DEPARTMENT OF COMMERCE AND LABOR
BUREAU OF FOREIGN AND DOMESTIC COMMERCE
A. H. BALDWIN, Chief

SPECIAL AGENTS SERIES—No. 66

ELECTRICAL INSTRUMENTS AND METERS IN EUROPE

By

H. B. BROOKS
Commercial Agent of the Department of Commerce and Labor

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LETTER OF SUBMITTAL.

DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF FOREIGN AND DOMESTIC COMMERCE,
Washington, December 20, 1912.

SIR: I have the honor to submit herewith a series of reports by Commercial Agent H. B. Brooks dealing with the manufacture of electrical instruments and meters in Europe. The works of 31 leading firms are described, attention being paid to equipment, number of employees, and hours of labor, and especially to the nature of the products manufactured.

Respectfully,

A. H. BALDWIN,
Chief of Bureau.

To Hon. CHARLES NAGEL,
Secretary of Commerce and Labor.

ELECTRICAL INSTRUMENTS AND METERS IN EUROPE.

INTRODUCTION.

With the ever-increasing use of electricity in almost every branch of industry, the manufacture of electrical instruments and meters is becoming an important and highly specialized industry in which many complex problems arise. In view of the pioneer work in electrical measurements done in Europe, a visit was made to the principal European manufacturers to obtain such information in regard to their organization, methods, and products as would be of interest to American makers and users.

In presenting the following reports the writer wishes to acknowledge his obligations to the leading men in the electrical instrument and meter business in Europe, who have permitted inspection of their factories and placed interesting and valuable information at his disposal.

ENGLAND.

BRITISH THOMSON-HOUSTON CO. (LTD.).

The British Thomson-Houston Co. (Ltd.) is an English electrical manufacturing company affiliated with the General Electric Co. of Schenectady. Its works are located at Rugby, about 80 miles northwest of London. Its products cover a wide range, including dynamos, motors, steam turbines, electric-railway equipment, switchboards, control apparatus, electric lamps, electric-heating apparatus, etc.

The manufacture of meters is carried on in buildings used for other classes of work also, so that no description of buildings will be attempted here beyond the statement that they are of brick, several stories in height, and well constructed.

While English machine tools are given the preference, a number of American machines are used where they are better adapted for the work. Included in the latter are Garvin tapping machines, Bardin-Oliver turret lathes, and Brown & Sharpe special tools and automatics for small work. The machines are arranged with each type in banks, in some cases group driven by electric motors, individual motor drive being used where possible.

About 450 employees are engaged in the instrument and meter work, 30 per cent being females. These latter are employed chiefly on small assembly work. The working week consists of 52 hours.

SWITCHBOARD WATT-HOUR METERS.

The Thomson "integrating wattmeter" is made for switchboard service in sizes from 5 amperes to 10,000 amperes, two-wire, and from 50 to 3,000 amperes, three-wire. Above 500 amperes, the two-wire

meter is always of the astatic type. The commutator and brushes are of silver, and copper is still used for the drag disk. The two-wire meter of capacities from 600 amperes up has some interesting points of construction. The field coil (for currents from 600 to 1,200 amperes) is made up of copper strips in D shape, with the straight side at the bottom, and is electrically one turn. Two armatures are arranged on one shaft; one rotates within the D, the other below the flat side of the D. Instead of the familiar 8 or 12 part commutator, 2-part commutators are used, and each armature is electrically one coil. To make the torque more nearly uniform over a revolution, the planes of the coils of the two armatures are at right angles; to increase the torque, a number of soft-iron disks are placed within the coils.

From 1,500 to 10,000 amperes the armature construction is as described, and the field "coil" consists of a straight copper bar bridging the terminal studs; this field construction is familiar to meter users in the United States. In all the above-described Thomson meters a soft-iron box surrounds the drag magnets. The modifications of the two-wire meter to adapt it for three-wire service are obvious.

DIRECT-CURRENT HOUSE-SERVICE METERS.

Thomson meters of the house-service type are made in ranges of from 5 amperes to 600 amperes. The dials read in B. O. T. (Board of Trade) units.[1] For house service, however, the watt-hour meter is not popular in England, the ampere-hour meter being in much greater demand. The B. T. H. ampere-hour meter is of the mercury type. The current flows through a thin cylindrical copper cup contained in a mercury chamber. The cup revolves in a narrow air gap of a strong permanent magnet, the design being such as to reduce the air gap to the minimum. The magnetic field is at once the driving and the braking field. It is stated that the design is such as to render unnecessary the use of a compounding coil, and that the meter will start to register with a load of one-half of 1 per cent of its rated current. These meters are made for rated currents from 3 to 500 amperes.

The following data on the type MH mercury meter were furnished by the makers: Loss in series circuit at full load, 0.1 watt; drop in series circuit at full load, 0.02 volt; full-load torque, 35 millimeter-grams; speed of rotation at full load, about 55 revolutions per minute; weight of meter complete, 12.5 pounds.

The company states that ampere-hour meters, because of their simplicity, reliability, and small losses, are now in general use in England for direct-current circuits.

The mercury meter is also made in prepayment type, in 3-ampere and 5-ampere ranges. The switch is of the knife-blade type, and the prepayment mechanism is of purely mechanical construction. Other types of mercury meter are made for switchboard and for tramcar service.

SINGLE-PHASE WATT-HOUR METER.

The company's type RH single-phase induction watt-hour meter is similar in operating principle and external appearance to the type I, made in Lynn by the General Electric Co. The driving

[1] The kilowatt-hour is called in England a "Board of Trade unit," or often briefly a "unit."

element is fastened to the cast-iron base of the meter, and the moving element, magnets, and dial are attached to a cast frame that is screwed to projections on the meter base. The frame can thus be readily removed to give access to the coils, and replaced without altering the calibration of the meter.

The following data on the type RH meter were supplied by the makers: Loss in potential coil, 1.5 watts; loss in 5-ampere series coil, at full load, 0.55 watt; drop in 5-ampere series coil, at full load, 0.3 volt; full-load torque, all capacities, 50 millimeter-grams; weight of moving element, 25 grams; speed of rotation at full load, 35 to 40 revolutions per minute; weight of complete 5-ampere 110-volt meter, 8.5 pounds. Horizontal edgewise indicating instruments are made at the Rugby works in practically the same form as at Lynn.

The company obtains most of its materials from British sources, very little being supplied from the United States, sells its product largely in England, and exports to countries other than the United States and the Continent.

CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

The Cambridge Scientific Instrument Co. was formed in 1895, and erected factory buildings the same year at Cambridge, England. The original buildings have side and "lantern" lighting. At the time of the writer's visit (March, 1912) a new building was under construction, having the most advanced type of saw-tooth roof, with large glass area. The location of the works is very favorable as regards freedom from dust and dirt. The new building is of brick, one story high, with steel framework for the roof. Two rows of cast-iron pillars provide intermediate support for the roof framework, on account of the large span. The framework is covered on the outside with sheathing boards and slate, and on the inside with asbestos board.

In addition to the older one-story machine shops, there are several two-story buildings containing the offices, drafting rooms, testing rooms, etc. Each department of the works is driven by a separate 400-volt direct-current motor, current being bought from the local supply company at 2 cents per kilowatt hour.

METHODS AND EQUIPMENT.

The general process of manufacture is adapted to the special requirements of the company's business. Instead of producing a comparatively small number of instruments in large quantities, it produces a large number of types and forms, for any one of which the demand is necessarily not very great. To produce apparatus economically in lots of 10 to 25 requires careful study of methods. New instruments are being added from time to time, hence it is not feasible, as a rule, to make and store parts in quantity, though this is done in the case of some small detail parts.

A number of American machine tools are in use, including a Cincinnati universal milling machine, a Walker grinder, and several Star lathes. It was stated that while the best American machine tools (including such as Brown & Sharpe and Cincinnati Milling Machine Co.) are very good, nothing better being made, there is

too great a gap in quality between this grade and the next lower grade. Often a machine tool was wanted for work not of the highest grade, and in trying to get an American machine tool for such work, an inferior tool was received, not good enough for the work. It is stated that American tool designs generally are well thought out, but few firms carry the quality right through. It was further stated that there was a great and uncertain delay in the delivery of American machine tools.

A heavy semiautomatic turret lathe of German manufacture (Auerbach & Co., Dresden) is considered one of the most useful tools in the equipment. It is especially adapted to the machining of moderately heavy instrument parts in lots of 10 to 25. A heavy arm pivoted at the back of the lathe can be swung down, bringing a chaser against the work. This is especially useful for threading large tubing, saving the cost of large and expensive dies.

A high-speed sensitive drilling machine was required for light work and as nothing entirely meeting the requirements could be had on the market, the company designed and built two of these machines. They are used for drilling holes from $\frac{1}{100}$ inch to $\frac{1}{4}$ inch in brass or gun metal, the maximum speed being 6,000 revolutions per minute. The company also manufactures these machines for the market.

Broca galvanometers are used in the testing rooms; they are suspended from girders at a height of about $3\frac{1}{2}$ feet above the bench. A Nernst lamp projector is attached to the wall some distance below the galvanometer, and throws a circular spot of light traversed by the image of a vertical cross wire to a plane mirror in front of the galvanometer, whence it is reflected back to the plane mirror, down to another plane mirror set at 45 degrees to the vertical. From this last mirror the rays pass horizontally to a translucent scale in front of the observer. The Broca galvanometer is said to give a sensitivity rather higher than that of the Thomson reflecting galvanometer, but is very much less affected by stray field. It was stated that the moving about of millivoltmeters on the bench does not disturb the Broca galvanometers.

Over 130 employees are engaged in the work. Female labor is not employed. The working week consists of $53\frac{1}{2}$ hours. The company states that it has never experienced a strike.

TEMPERATURE-MEASURING APPARATUS.

The product of the company includes apparatus for temperature measurements, electrical and physical apparatus for laboratory use, and a variety of other scientific apparatus. Considerable attention is devoted to the design and construction of apparatus for special requirements. Recent instruments of this kind include 4-meter, 24-meter, and 50-meter comparators, apparatus for the investigation of mine explosions, and sea-wave recording apparatus. The company is sole maker of the Féry radiation pyrometers for England and several other countries, and has for years given special attention to the manufacture of thermoelectric pyrometers and their accessories (indicators and recorders), and also platinum resistance thermometers. The "thread recorder" used with thermocouples has

a suspended coil galvanometer whose pointer is depressed by clockwork once a minute, pressing an inked thread against a paper chart.

GALVANOMETERS.

Recent improvements in Cambridge moving-coil galvanometers include the use of specially pure silver wire, narrow coils, and gold-plated silver suspensions. The coils are specially treated to remove any magnetic impurities.

The Broca galvanometer is of the type having fixed coils and moving magnetic system. The special feature is the form of this system, which consists of two steel wires hung vertically close together. Each wire has like poles at its ends and a consequent pole in the middle. The magnetic system is thus astatic.

The Einthoven string galvanometer has a single fine wire (or silvered glass or quartz fiber) in the intense field of a powerful electromagnet having a narrow air gap. When a current flows through the "string," the latter moves across the field. The motion is observed with a microscope, or by projecting the image of the string on a screen. The prominent features of this galvanometer are its extremely short period (as low as 0.01 second), great sensitivity, and freedom from inductance and capacity.

The Duddell thermogalvanometer has a loop of silver wire which is closed at the bottom by a thermocouple of bismuth and antimony and is suspended in the field of a permanent magnet. The current to be measured flows through a heating coil placed below the thermocouple. The heat sets up a current in the silver loop and the latter is deflected more or less, according to the strength of the current. The principle of operation is such that the same deflection is obtained for a given current, either direct or alternating, and regardless of the frequency or wave form of the latter. It may be used for measuring currents used in wireless telegraphy, and is sensitive enough, with a suitable heater, to measure telephonic currents.

The Duddell oscillograph is made for voltages up to 50,000. In addition to the high-frequency type having an electromagnet, a simpler form is made with a permanent magnet. This is more suitable for high-tension work and in cases where the instrument must be frequently moved from place to place.

Materials are obtained chiefly from England, France, and Germany. Purchases from America are limited mainly to tools. The product is marketed in all civilized countries.

EDISON & SWAN ELECTRIC LIGHT CO. (LTD.).

The Edison & Swan Electric Light Co. (Ltd.) was formed in 1884 for the manufacture of incandescent lamps and fittings. The company's works are located at Ponders End, Middlesex, north of London, and are very extensive. The equipment includes machine tools of English, German, and American makes. The company's product is primarily electric-lighting apparatus and supplies, including arc and incandescent lamps, switchboards, and wiring devices. In addition, various patented specialties are made for foreign owners, who are required by British law to manufacture articles in England in order to maintain their English patent rights.

AMMETER SHUNTS WITH TERMINALS CAST ON.

As a part of its regular product the company makes electrical measuring instruments. The direct-current instruments are of the moving-coil type. The company uses manganin for ammeter shunts on account of its low thermal electromotive force. Most makers construct ammeter shunts by soldering the resistance metal into slots cut into the brass or copper terminals. The Edison & Swan Co. casts the terminal around the resistance-metal strips. It is claimed that when this is carefully done a joint results that is practically perfect, and that such shunts will carry much heavier overloads without damage than will the usual soldered shunts. The standard shunt drop at full load is 75 millivolts. The adoption of this figure is due to the influence of the British standard specification for ammeters and voltmeters.

SOFT-IRON INSTRUMENTS—COST INDICATOR.

Soft-iron instruments are constructed on the repulsion principle, with spring control or gravity control. Air damping is used for many of the soft-iron instruments, the use of die castings making this possible without too great expense. Soft-iron ammeters are also made as power gauges, the scale being marked in horsepower for some particular motor. To do this the customer sends in the test curve or data for the motor, and the scale of the ammeter is marked accordingly. The "cost indicator" made by the company is an ammeter (either switchboard or portable) whose scale is marked in cost per 100 hours at some specified rate of charge for electricity. Instruments of this kind should be very useful in selling electric lamps, heating devices, etc., as the result indicated requires no computation or explanation to the customer, as is necessary when instruments reading in electrical units are used.

CARDEW VOLTMETER—CALIBRATING THE INSTRUMENTS—LABOR.

The Cardew voltmeter is still listed in the company's catalogue, and it is said that they are still used in some central stations. The company also makes portable instruments, both direct current and alternating current, in various forms, including portable instruments with gravity control, which, so far as the writer is aware, are unknown in the United States.

In calibrating the instruments manufactured, the company uses secondary standard instruments, both alternating-current and direct-current. The alternating-current secondary standards are periodically checked by comparison with Kelvin balances. These balances are sent once a year to the Board of Trade (Government) laboratory for certification of correctness. The direct-current secondary standards are checked by means of a potentiometer.

The company obtains most of the material used in instrument manufacture from English sources, very little American material being used. The average wages are about 8 shillings ($1.95) per week for girls and 40 shillings ($9.73) per week for men. The ordinary working week is 49½ hours. The company's product is marketed principally in the United Kingdom, but a considerable portion is exported to the colonies and other countries. Very little, if any, is marketed in the United States.

ELECTRICAL APPARATUS CO. (LTD.).

The works of the Electrical Apparatus Co. (Ltd.) are located near Vauxhall Station, in the southern part of London. The present building will accommodate 250 workmen, and the site will permit extension of the building to accommodate 200 more. The company has practically no American equipment, as it finds the products of the English machine-tool makers satisfactory. The equipment is very complete, the company making even such standard parts as nuts and screws. No American material is used, with the possible exception of copper. Female labor is employed only in the offices.

A prominent feature of the company's work is the manufacture of motor starters of original design, including a slow-motion, or "fool-proof," starter, in which a ratchet motion obliges the operator to advance the starting lever from the middle of one contact step to the middle of the next one, it being impossible to advance more than one step at a time. If for any reason it is desirable to throw the lever back to the open-circuit position, or if the voltage fails while the motor is running, there is no impediment to the free backward movement of the lever.

THE E. A. C. AMPERE-HOUR METER.

The product of chief interest is the company's ampere-hour meter, which is designated as the E. A. C. high-torque meter. The general form is very similar to that of small induction watt-hour meters brought out by several of the leading American makers a year or two ago.

The armature coils, three in number, are wound in "pancake" form and are inclosed within two thin aluminum disks, with suitable insulation. The disks are spun together. The complete armature is tested with 500 volts for insulation between shaft and circuit. The commutator has three segments of 18-carat gold insulated from the steel shaft by a tube of ebonite. The brushes are tipped with gold contacts, which make an edgewise contact on the commutator; thus a small total pressure of the brush on the commutator gives a relatively large pressure per unit of contact surface and tends to insure good contact. The lower shaft end, which is not removable, is protected by a brass cap.

The armature revolves in the field of two strong permanent magnets, which thus supply the working field for the armature coils and the retarding field for the drag disk. The winding is such as to require about 1 volt drop at full load, the armature current being about 0.25 ampere. The armature resistance is thus relatively high, and variations of brush contact resistance are said to have a negligible effect upon the accuracy.

NONINDUCTIVE SHUNT—DETAILS OF METER CONSTRUCTION.

The armature circuit is connected in parallel with an alloy shunt of negligible temperature coefficient. At first thought it would appear that the inductance of a direct-current shunt was of no consequence. However, it has been found that when a meter with an inductive shunt is subjected to a short circuit, the inductance of the

shunt tends to increase the relative proportion of current through the armature. The $1\frac{1}{2}$ and $2\frac{1}{2}$ ampere meters as now constructed have the shunt wire reflexed to give a more nearly noninductive shunt.

Other constructional details of the meter are given as follows: Magnets are of tungsten steel; jewels of Ceylon sapphire; mica only is used as insulating material. A substantial cast-iron case is used, with provision for excluding dust and dampness. The diameter of the commutator is given as 0.07 inch; weight of moving element, 45 grams; full-load speed, about 150 revolutions per minute; full-load torque, 200 millimeter grams.

Meters of the same capacity are tested in series, using indicating ammeter and stop watch. Several of the ammeters are of American make. The company's output of meters is about 10,000 per year. These are sold chiefly to English central stations.

ELLIOTT BROS.

The firm of Elliott Bros., manufacturers of electrical and mechanical instruments, was founded in 1800, and thus has the distinction of being the longest established in its line in England, if not in the world. In the course of its growth the firm's business was carried on in various locations in London. The buildings at present occupied at Lewisham, in the suburbs of London, were completed and entered in 1900, and are accordingly called the "Century Works."

The main shop and also the main test room are one-story structures, each of which is built integral with a two-story portion. The one-story construction was employed to provide roof lighting for those important parts of the works. The upper floor of the test-room building contains the offices. The cabinet shop and the group of buildings containing the power house, foundry, etc., are one-story buildings.

AMERICAN METHODS—EQUIPMENT.

The firm has adopted American methods and uses many American tools, including Brown & Sharpe milling machines; grinders of American make are also in use. The firm has a high regard for American machine tools of the better class, but since the English makers have greatly improved their products in recent years it is possible to purchase English equipment, which the firm naturally prefers to do, other things being equal. Herbert's milling machines, for example, are considered by the firm to be very good, and they can usually be bought for less than the high-class American milling machines. In the tool room are lathes made by Brown & Sharpe, Providence, R. I.; Pratt & Whitney, Hartford, Conn.; and Ludwig Loewe & Co., Berlin, Germany; American-made milling machines and shapers are also used.

Group driving is used for most of the machines. A 200-volt direct-current motor drives one or several line shafts. The motors are of uniform size and machines enough to load each motor are connected to it. In the case of a number of small bench lathes the use of individual drive has been found both convenient and economical of power. Each lathe is driven by a one-fourth horsepower direct-current motor mounted on a vertical support from the back of the bench; the round driving belt comes down to the lathe at about 45°

to the vertical. The motor has a three-step cone pulley to suit the cone pulley of the lathe; hence no intermediate shafting or gearing is necessary. The motor is started or stopped by a simple switch. The arrangement seems to be a very convenient one for light work, where frequent stoppages occur.

The foundry is equipped with coke and gas furnaces, and produces all the castings used; these are of copper, brass, gun metal, and aluminum. At one time many instrument parts were made by the die-casting process, but this has been given up, as later methods have been devised by which parts can be produced at equally low cost (in some cases at lower cost) on "capstan" (turret) lathes. Gas-fired ovens are used in the smith's shop for hardening and tempering; the correct temperatures are determined by electrical pyrometer.

ELECTRICAL ENERGY—CABINET SHOP—PRINTING DEPARTMENT.

The electrical energy used in the works is purchased from a local company, the supply being at 3,000 volts alternating current. This is stepped down, and is converted by two 100-kilowatt motor generators to 200 volts direct current.

The cabinet shop is equipped with motor-driven machine tools, and produces a large amount of high-grade woodwork for instrument bases and cases, telegraph apparatus, etc. A great deal of woodwork for telegraph and other apparatus intended for use in hot climates is made from teak. This wood, which is but little known in the United States, is immune from attack by ants.

A printing department is maintained that not only provides most of the regular printing and stationery but is also equipped with three special machines for ruling, printing, and punching the long rolls of paper used in the Elliott recording instruments. The paper for this purpose is bought in large quantities to close specifications as to quality, thickness, and width, and is given the special treatment that experience has shown to be necessary for the best results.

LABOR AND WAGES.

About 450 employees are engaged in the works, only 21 being female. The latter are employed only in the offices and in some kinds of calibration and testing. The firm's experience is that boys are better for winding coils. Girls are said to do well at light routine work, but are content to go on year after year doing the same kind of work, whereas boys are ambitious and desire to learn as many things as possible. A girl may be taught to calibrate 100-ampere ammeters, for example, and will do very well on a lot of these, but if she is to do such instruments one day, another range the next day, and so on, she does not make a success of it and requires too much superintendence. The same characteristic makes her unsuitable for repair work. The working hours for boys and men in the shops are from 7.30 to 12.30 and from 1.30 to 6; work stops at 12.30 on Saturdays. Girls begin work at 9 o'clock, but otherwise the hours are the same as for the men.

The piecework system is used for nearly all parts made in quantity. The average instrument maker earns 8 to 9 pence (16 to 18 cents) per hour. Some of the highest-class men on this work and

also the toolmakers earn 10 pence to 1 shilling (20 to 24 cents) an hour, and can do better. The firm never cuts the piecework price unless the method of production is changed so as to reduce the amount of work required. The "time-limit" system is used in the testing room; thus, if 8 hours is the allotted time for a particular piece of work, and a man does it in 6 hours, he gets pay for one of the hours saved and the firm saves the other hour. In some English electrical works boys are required to work without pay on entering, or even to pay a premium for the privilege of working. This is not the practice at the works of Elliott Bros.; a boy on entering is paid a minimum of 1¼ pence (2½ cents) per hour; his pay is then raised as he acquires skill.

There are about a dozen labor unions, all independent, among the employees, each comprising the men of a particular section of the works. Very little trouble has been experienced from strikes. In January, 1912, there were 3 men employed who had been with the firm continuously for over 40 years, 8 who had been employed over 30 years, 13 over 20 years, and a large number over 10 years.

A number of organizations for the welfare of the employees are in effect. These are known as the amusements committee, the sick club (which pays sick benefits), the loan club, the holiday fund, the library, and the orchestra, which last is under the management of the amusements committee. In addition, written suggestions for improvement of product, methods, etc., are invited from the employees, and a suitable return is made for suggestions which can be used. These features, it is stated, are due to the example of the National Cash Register Co., of Dayton, Ohio.

MATERIALS—THE FIRM'S PRODUCTS.

The firm obtains practically all its materials from British sources, although some specialties, such as Norton grinding wheels, are obtained from America. Aside from the natural desire of the firm to use British material, the American maker or dealer usually asks higher prices, and the long time required to obtain American supplies is a serious drawback. American dealers might compete successfully for large orders with a long time for delivery (say, several months).

The firm's product covers a wide range. Moving-coil direct-current instruments are made in switchboard and in portable forms; alternating-current instruments are made on both the moving-iron and the electrodynamometer principle; both alternating-current and direct-current recording instruments are made. Current and potential transformers (switchboard and portable) are made for currents up to 10,000 amperes and voltages up to 20,000. Leakage indicators, alternating-current and direct-current, are made in switchboard form; these instruments are used in England in compliance with the Home Office regulations for the supply of electricity in mines. Portable testing sets are made consisting of two electrodynamometer instruments in a single case. In addition to the more usual combination of voltmeter and ammeter the following combinations are furnished: Two voltmeters, two ammeters, two wattmeters, voltmeter and ammeter, voltmeter and wattmeter, ammeter and wattmeter. Triple sets are also made, having any desired combination of three of the above units. Other portable sets include a fault-localizing bridge, a rail-bond test set, and a photometer.

INTERESTING FEATURES OF THE FIRM'S INSTRUMENTS.

Both the switchboard and portable instruments have window openings of liberal size, giving well-lighted scales, and facilitating the reading of instruments too high from the floor line. Ammeter shunts are electrically interchangeable, as are the millivoltmeters. Furthermore, the shunts are mechanically interchangeable, and this feature is considered to be worth the cost, although requiring a heavy outlay for jigs. Switchbcard shunts are made up to 15,000 amperes capacity, and the standard drop at full load is 75 millivolts. This value is due to the British Standard Specification for Ammeters and Voltmeters, Report No. 49 of the Engineering Standards Committee.

The resistance material used for the switchboard shunts is eureka alloy, which is extensively used by the British makers; its properties are substantially the same as those of constantan, which is sold in the United States under the trade names of "Advance" and "Ia Ia." Manganin is used for portable shunts to avoid the thermoelectric errors that would be of consequence in the more accurate work for which portable instruments are often employed, such as testing consumers' meters.

All of the firm's precision direct-current ammeters are provided with a temperature-compensating arrangement devised by A. Campbell (see Journal of the Proceedings of the Institution of Electrical Engineers, vol. 35, p. 197). This consists of four coils connected as a Wheatstone bridge; two diagonally opposite arms are of manganin and the other two are of copper. The two manganin coils are usually equal, and the copper coils are equal; the relative values of copper and manganin coils are such that the bridge is unbalanced. The millivoltmeter is connected as one diagonal of the bridge, and the other two corners are connected by leads to the potential terminals of the ammeter shunt. This plan is said to give complete temperature compensation with a shunt drop equal to three times the copper drop in the millivoltmeter.

Alternating-current instruments on the electrodynamometer principle are made with moving coils of aluminum wire, surrounding the spherical fixed coil. The use of aluminum wire reduces the moment of inertia of the coil very considerably. These instruments have permanent magnet damping.

SHUNTED WATTMETER.

A novel alternating-current instrument made by the firm is the shunted wattmeter, which was produced in order to avoid the constructional difficulties encountered in "straight-through" wattmeters of the usual type for heavy currents, as well as to provide a wattmeter whose current range can be readily changed. A question that will arise at once is that of possible error due to the lag of the current in the series winding of the wattmeter with respect to the current in the shunt. Following is a brief outline of the manner in which this question is met: The moving coil is the current coil and surrounds the spherical fixed coil, which is wound with relatively fine wire. This fixed coil, with a noninductive added resistance of low temperature coefficient, forms the potential circuit. The angle of lag in this

circuit is somewhat less than the angle of lag of the current in the moving coil with respect to the line current; hence the instrument is made to read correctly by adding noninductive resistance to the moving-coil circuit. The adjustment of this resistance is conveniently made by passing the rated current through the shunt from one armature of a two-alternator set and applying rated voltage from the other armature to the potential circuit. By means of a standard wattmeter of the "straight-through" type whose windings are in the same circuits any small adjustment is made that is needed to bring the current and the voltage into quadrature. The small deflection of the shunted wattmeter is then reduced to zero by adjustment of the added resistance in series with the moving (current) coil. The shunt is made of manganin, while the current-coil circuit is part copper and part manganin. With a drop on the shunt at full load of about one volt, the proportions of copper and manganin are such as to require a temperature correction of about 0.2 per cent per degree centigrade. Shunted electrodynamometer ammeters are also made.

MOVING-IRON AMMETERS—FORMS OF RECORDING INSTRUMENTS.

Moving-iron ammeters are made on the "straight-through" principle up to five amperes; above that, five-ampere ammeters are used with manganin shunts. This allows the same instrument to be used on either alternating or direct current. When only alternating current is to be measured, current transformers may be used in place of the shunts. Current transformers for switchboard use have the secondary winding highly insulated, and consequently on high-voltage circuits the transformer as a whole must be insulated, usually by mounting it on a porcelain insulator, in case the primary line is not strong enough to support the weight of the transformer. This is the reverse of the usual American practice, which is to provide high insulation on the high-voltage coil; since the secondary circuit is usually grounded, it is not necessary to insulate it highly from the core and case. In constructing potential transformers, the firm follows the usual practice of highly insulating the primary winding.

Recording instruments are made in switchboard and portable forms. For alternating current an electrodynamometer system is used, with an oil dashpot for damping; for direct current the moving-coil system is used. The clocks are made by the firm; they are interchangeable and can be readily removed from the case, so that a user of a number of Elliott recorders can keep a spare clock. An interesting accessory for the recorder is the "telltale attachment," which is simply a small hole covered by a spring flap, at the side of the recorder. A small plunger is provided that will pass through the hole and has a rubber initial on the end. This device is intended for use when it is desired to have a check on the presence of the switchboard attendant, who is required to ink the initial at stated intervals and stamp the paper chart.

RAIL-BOND TEST SET—RESISTANCES.

A rail-bond test set made by the firm consists of two center-zero millivoltmeters mounted in a carrying case. By means of contact rods one millivoltmeter is connected across the rail joint, while the

other is connected across a portion of the solid rail. By varying the position of one of the contact rods both millivoltmeters are made to give the same reading; the distance between two of the contact points then gives the length of solid rail whose resistance is equal to that of the joint.

The firm makes standard resistances, both laboratory and workshop forms, for oil cooling and for air cooling; also plug and dial resistance boxes and bridges. Manganin wire and sheet are used, though, in common with a number of other English makers, the firm considers it a less reliable alloy than platinum-silver or eureka. This latter is generally preferred for higher values of resistance, where its high thermal electromotive force against copper is not a disadvantage. The Elliott five-dial universal shunt is a piece of resistance apparatus intended to have as many uses as possible. It may be used as an Ayrton-Mather universal galvanometer shunt, as a Wheatstone bridge, a variable rheostat, or a potentiometer. It is stated that a submarine-cable station is practically fully equipped for testing with one of these instruments and a galvanometer. An interesting constructional detail is that the contact studs are faced with gold and the levers with platinum. The Elliott potentiometer has a dial of 149 equal coils, in series with a slide wire whose resistance is equal to that of one coil of the dial.

MISCELLANEOUS APPARATUS.

Other apparatus made by Elliott Bros. includes magnetic testing apparatus (the Ewing permeability bridge and the Ewing hysteresis tester) and telegraph apparatus, including the Wheatstone apparatus for rapid telegraphy and the Baudot printing telegraph. Galvanometers are made in many patterns, from the simple detector to the elaborate eight-coil high-insulation Thomson; moving-coil galvanometers are supplied in a variety of forms. Engineering instruments include speed indicators on both mechanical and electrical principles, micrometer calipers, steam-engine indicators, and the Wimperis accelerometer and gradient measurer. A special precision lathe is in use for cutting the screws of the micrometers. The lead screw is a very accurate one, and its small errors are prevented from repeating themselves in the screws cut by the lathe. To these may be added surveying instruments, in the manufacture of which Elliott Bros. have had a very long experience.

The Partridge sparklet fuse made by Elliott Bros. is intended for the protection of high-voltage circuits. It contains two "sparklets" such as are used in aerating liquids. These are placed so that the arc that follows the melting of the fuse melts the thin metal of the sparklets; the resulting rush of gas blows out the arc.

The firm makes a large variety of apparatus for use on shipboard, of which the most interesting from an electrical standpoint is the Anschutz gyro compass. This compass operates on the principle of the gyroscope, the rotating portion being part of an induction motor operating at 20,000 revolutions per minute. To drive this motor, high-frequency currents are supplied from a small motor-generator set; on account of the high speed and the large moment of inertia, half an hour is required to bring the compass up from rest to full speed, and it will run several hours after the driving current is

broken. This compass makes possible the use of subsidiary compasses about the ship, all of which are under the control of the master compass.

CALIBRATING AND TESTING ELECTRICAL INSTRUMENTS.

In calibrating and testing electrical instruments use is made of "substandard" instruments, which are periodically checked by reference to standards of the best grade. For example, precision direct-current instruments are used as substandards, and are periodically checked against potentiometers. As standard instruments for alternating-current, electrodynamometer instruments are used whose construction is such as to avoid errors due to eddy currents, skin effect, etc. These are checked on direct current. Alternating currents, single and polyphase, are obtained from motor generators. Eight large storage cells, which can be connected in various groupings, provide heavy currents for testing large ammeters and shunts. A battery of 1,000 small storage cells (made in the firm's works) is used for small currents at voltages up to 2,000.

The products of the Century Works are marketed throughout the world, a large part of the production being exported. On account of the high tariff only a relatively small amount goes to the United States, where sales of late years have been confined principally to recording instruments.

EVERETT, EDGCUMBE & CO. (LTD.).

The Collindale works of Everett, Edgcumbe & Co. (Ltd.) are located at Hendon, one of the northwest suburbs of London. The business was founded in 1896 by E. I. Everett, and was carried on in several locations in the city of London. In 1900 Kenelm Edgcumbe became a member of the firm. The city quarters becoming successively inadequate, it was decided to build a factory in the suburbs, in order to secure more space and also better light and air and freedom from dust. A site of 1½ acres was secured, and the buildings were designed and built by the firm. They were completed and manufacturing was begun in 1905.

BUILDINGS AND EQUIPMENT.

The principal buildings are of brick, two stories high. Although the weaving-shed roof was not used, the roof contains sufficient glass to give good lighting. The main building contains the machine shop on the ground floor; the upper floor contains the stores of finished parts and movements, and accommodates the work of winding, assembling, and testing. The office building contains the general offices on the first floor; the upper floor contains the cost department, the drafting room, and the experimental laboratory. The power plant is housed in a smaller building; it consists of a gas engine driving a direct-current generator, with a motor generator connected to the town mains as a reserve unit. The current generated in this plant is used for lighting, testing, and charging storage batteries. A gas engine drives the machine shop by line shafting. Both engines are operated by suction gas, and a fan is used to transmit some of the gas to another building, where it is used to heat plating baths

and enameling ovens. Another building is devoted to woodworking, and is equipped with power machines.

In the equipment of the machine shop American makers are fairly well represented. Brown & Sharpe Manufacturing Co., Cincinnati Milling Machine Co., and Garvin Machine Co. milling machines, and W. F. & J. Barnes Co. and Hoefler drills are in use, as well as a lathe, a power hack saw, a punch press, and many small tools of American manufacture.

DIE CASTINGS—AIR-DAMPING BOXES.

The reduction of manufacturing costs is a very urgent problem with the English instrument maker. Everett, Edgcumbe & Co. have studied this problem with good results. They use die castings largely, and having in mind the trouble caused by the use of certain unstable aluminum alloys for this purpose, they use a mixture which contains none of the treacherous metal, zinc, whose presence in some alloys is liable to cause deterioration. The spools of moving-iron instruments are die cast. The air-damping boxes with which many [1] of the firm's instruments are fitted are not made of die castings, as might be supposed, but are stamped from sheet brass in halves, which are then soldered together.

MILLING POLE PIECES—COIL-WINDING MACHINE.

An interesting machine which effects economy in machining cast-iron pole pieces is a double milling machine, having face cutters with inserted teeth. The two cutters face each other, one being carried by the spindle of a fixed head, the other by the spindle of a head which can be made to move toward or from the fixed head, so as to vary the distance between the milled surfaces. This movable head has a micrometer adjustment, and can be clamped to the bed when the desired distance is obtained.

For winding finer sizes of wire, as used in voltmeter coils, resistance spools, etc., special machines are used. These have a carriage for guiding the wire as it winds onto the bobbin, the carriage containing a half nut which rests on a feed screw and can be lifted off if desired. The feed-screw shaft carries two clutch pulleys which are revolved in opposite directions by a single round belt which is driven by a pulley on the head spindle carrying the bobbin to be wound; by exchanging this latter pulley for others of different sizes the pitch can be varied to suit various diameters of wire. The belt passes down from one clutch pulley, through a hole in the bench, then over a weighted pulley [2] and back over the other clutch pulley. This weighted pulley not only enables a single driving belt to run the two clutch pulleys in opposite directions, but also automatically keeps the right tension on the belt, and permits changes of size of the driving pulley without change of belt tension. The machine is belt-driven by a one-fourth horsepower motor under the bench, which is started and stopped by a single switch. The coil to be wound is carried in any suitable way on the head spindle, and a movable tail stock is pro-

[1] This includes all instruments except those of the moving-coil type (which are inherently aperiodic), including "motor gauges." An instrument with no damping is almost worthless on fluctuating loads, and it is to be hoped that makers everywhere will endeavor to produce damped instruments at prices low enough to make the undamped instrument disappear.

[2] As used in telephone switchboards to take up the slack in the cords.

vided to support the outer end of long bobbins or resistance cards. A very simple and effective counter is provided for indicating the number of turns of wire wound. This consists of two 100-tooth wheels made of heavy sheet brass; one is driven by a worm on the head spindle, and carries a 10-tooth pinion which drives the second wheel. These wheels are carried on vertical studs projecting up from the frame. An index which extends to the circumference is then slipped on to each stud, friction tight. The wheels are marked with 100 divisions each, and thus count up to 1,000 turns. The indexes may be turned to any desired position to read zero for the next coil to be wound, and, if desired, the indexes may be slipped up the spindle and the gears raised so as to be out of mesh with each other and the worm, when they may be turned to any desired position and again brought into mesh.

METHOD OF MAKING INSTRUMENT SCALES.

All scales are made to fit the particular instrument, no law being assumed for a type and no printed or engraved scales being used. When an instrument is ready for calibration a uniformly divided scale is put in it, and readings are taken on this scale for various values of current, voltage, or other quantity concerned, and corresponding readings are taken on a working standard instrument.[1] These readings are given to the operator of a special scale-dividing machine, by means of which a scale may be quickly made to suit the particular instrument. The operation of this machine is simple and rapid, and makes it possible to locate every mark on the scale where it should be.[2]

In addition, a number of special machines are in use for printing the figures on instrument scales and recorder charts. These machines were designed by E. I. Everett, to whom the writer is indebted for the opportunity to see them and to give the above description of the winding machine.

EQUIPMENT FOR TESTING—LABOR CONDITIONS.

An equipment of large storage cells provides heavy current at low voltage for ammeter testing, and a large number of small cells provide for voltmeter testing. To supply alternating currents, small motor generators are located in the testing room. One of these consists of a direct-current motor driving two alternators through clamp couplings. One alternator may be used to supply the current coil of a wattmeter or power-factor indicator, the other supplying the voltage. By shifting one of the couplings any desired phase relation between the current and the voltage may be obtained.

Special attention is given by the firm to the matter of adequate insulation of its instruments. Before being sent out each instrument is given an insulation test of from 1,500 to 2,000 volts. This applies to all instruments irrespective of price or type.

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[1] These are in turn checked by laboratory standards; for example, direct-current voltmeters used as working standards are periodically tested by reference to a potentiometer.

[2] Some makers locate every tenth mark by test, and consider it sufficient to divide each space into 10 equal parts. For moving-coil instruments this no doubt answers very well, but in alternating-current instruments whose scales vary a great deal in length of a division in different parts, this method is poor, as may be seen on a scale made in this way, by comparing the length of certain adjacent spaces, say the one from the ninth division line to the tenth with the one from the tenth to the eleventh.

About 25 per cent of the employees are girls, who assemble the working parts of instruments, apply enamel to cases, wind coils, adjust the simpler kinds of instruments, do routine calibrating, and make the scales. The working week consists of 50 hours. The firm states that some labor unions exist among the employees, but that no trouble from strikes has been experienced. The comfort of the employees has been looked after; the buildings are evenly heated by the hot-water system,[1] and have plenty of light; mess rooms are provided, one for men and boys, another for the girls. Meals are supplied to the employees at reasonable prices.

OUTLINE OF PRODUCTS—MOVING-COIL INSTRUMENTS.

The products of Everett, Edgcumbe & Co., while limited almost exclusively to technical instruments, cover a wide range. Moving-coil, moving-iron, and electrodynamometer principles are used in switchboard and portable forms, and electrostatic instruments are supplied as switchboard voltmeters and as leakage indicators, or "ground detectors" as they are called in the United States. Recording instruments are made with disk charts and with roll charts, in which an ink line is drawn; an inkless recorder is also made.

The moving-coil instruments differ from the usual examples of this type in that a single control spring is used. This spring does not conduct current, as this is accomplished by two very flexible ligaments at the end of the coil opposite the one carrying the spring.[2] These ligaments are protected from injury by a heavy block of molded insulating material to which the magnet system is attached and which supports the system in the metal case. The jewel screws are carried by the central iron core, the pivots being on the inside of the coil frame and mechanically attached to it, avoiding the use of cement. The magnets are artificially aged, and as the decay of permanent magnets is thought of by some users as dependent, to some extent at least, on the passage of time, the following quotation from the firm's catalogue is of interest: "These three physical effects [variations in temperature, external magnetizing forces, and mechanical vibration] are the only ones which affect the permanency of a modern high-class closed-circuit magnet. Passage of time has, in itself, no effect on the magnetism." A compensating moving-coil voltmeter is made which indicates the voltage at the distant end of a feeder without the use of pilot wires.[3]

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[1] The merits of this system seem to be imperfectly appreciated in England, where the wasteful open fire, with the resulting smoke nuisance and great inequality of heating, is still generally used.

[2] This construction was tried some years ago in the United States, thin silver ligaments being used. These were subject to deterioration, which was most probably due to the action of free sulphur in the soft rubber tubing used to protect connecting wires within the instrument case. Everett, Edgcumbe & Co. use no rubber tubing for this purpose, and state that no trouble has occurred due to failure of the ligaments. The use of braided sleeving instead of rubber tubing for protecting connecting wires in instruments is now common in the better class of switchboard and portable instruments made in the United States.

[3] An instrument for this purpose was constructed by the writer in 1893, in which a single moving system was used, wound with fine wire as for an ordinary voltmeter, and with coarse wire (as for a millivoltmeter) over the fine wire. Two springs and two fine wire helices were used to lead the two currents in and out. The fine wire, in series with a suitable high resistance, was connected across the bus bars, and the coarse winding was connected to a shunt, or to potential points at the proper distance apart on one of the feeder conductors. See Electrical World, vol. 49, p. 1317; 1907. For another method of accomplishing the same result, see paper by F. E. Haskell, Electrical World, vol. 49, p. 1031; 1907.

MOVING-IRON INSTRUMENTS.

Moving-iron instruments are made on the repulsion principle, and also in two forms on the plunger principle; each of the three is used where it is best adapted, taking into consideration questions of cost, accuracy required, and whether a given instrument is for use on alternating current only or on both alternating and direct currents. Gravity control is used for some lines of switchboard moving-iron instruments, and spring control for others. All these have air damping. In addition to a legible scale and liberal window openings, the firm's switchboard instruments have cases which are commendable because neat and free from superfluous lettering and ornamentation, which tends to distract attention from the scale itself.

One type of moving-iron instrument, which the firm calls the "Universal," is supplied for use on either alternating or direct current, without change of calibration, in both switchboard and portable forms. Portable ammeters of this type are supplied for use in connection with a set of shunts, the range of the instrument alone being 1 to 15 amperes. To cut down the temperature correction, some extra resistance ("swamp") is used in series with the copper coil, the extra resistance having a negligible temperature coefficient. The drop on the shunts at full load is about 185 millivolts.

The firm constructs water-tight moving-iron ammeters and voltmeters for use where conditions are severe, as in mines or on shipboard. The cases are of cast iron for ordinary uses, bronze for shipboard, and have two distinct compartments. One of these contains the actuating coil and the terminals; the cables enter this compartment through glands. The other compartment contains the moving parts and the scale. Both compartments are made water-tight by the use of asbestos packing under the covers. Each instrument is tested by immersion in water at a depth of 4 feet; no sign of moisture in the case must appear. The type of movement is such that the same instrument may be used on direct or on alternating current, and the design is said to be so liberal that overloads of 200 or 300 per cent are withstood without injury.

ELECTRODYNAMOMETER AND ELECTROSTATIC INSTRUMENTS.

The electrodynamometer principle is used by the firm in constructing switchboard ammeters, voltmeters, and wattmeters. Where such instruments are to be used in locations subject to strong and variable stray magnetic fields, an astatic movement is supplied on request. In addition to wattmeters of standard switchboard grade, an "industrial" wattmeter is also made, which is furnished at a price lower than that of the corresponding range of regular switchboard wattmeter.

Electrostatic voltmeters of the suspension type are made by the firm for maximum voltages of 130 up to 1,500. From 2,000 to 6,000 volts, the round pattern pivoted construction is used. For extra high voltages (maximum scale reading of 30,000 to 200,000 volts) a special type is made.

INDUCTION INSTRUMENTS—THE "PALLER."

Induction ammeters and voltmeters are made by the firm in round pattern, for switchboard use only. Other alternating-current in-

struments include power-factor indicators, single and polyphase, switchboard and portable forms; frequency meters on the vibrating-reed principle, and a rotary synchronizer. In connection with the latter, an alternating-current paralleling voltmeter is supplied, called the "paller." The various difficulties that would be encountered in attempting to subtract electrically the voltages of the bus bars and incoming machine, using a single voltmeter to read the difference, are avoided by using two mechanically coupled voltmeter movements, each working at the normal current and position of moving element (and hence with normal sensitiveness to small changes of voltage), and subtracting their torques mechanically.

GROUND DETECTORS—GRAPHIC INSTRUMENTS.

Leakage indicators, or ground detectors, are made for central station and mine use. For voltages from 2,000 up the electrostatic principle is used; for low voltages the moving-coil and moving-iron systems are used.

The line of graphic[1] instruments made by the firm includes round disk-chart pattern, made as ammeters and voltmeters, in both astatic moving-iron type and moving-coil type; pen pattern, for roll charts, and also the "inkless synchronized" pattern for roll charts, both made in moving-coil and also in astatic moving-iron types. In the inkless pattern the index is ordinarily free from the chart, and hence ready to take up its proper position without friction. In place of the usual pen the index has a steel stylus. At intervals of five seconds an electric circuit through a solenoid in the graphic instrument is closed by a master clock, and the stylus is pressed against a typewriter ribbon, thus making a dot on the chart. This makes a practically continuous line, unless the quantity to be measured is changing rapidly, in which case more frequent depressions of the stylus can be arranged for. The inkless synchronized pattern is especially adapted for use in graphic power-factor meters, since the forces acting are relatively small, and pen friction would cause serious errors. Combined graphic instruments are made to record two quantities on the same chart; for example, the volts and amperes on a particular circuit.

RESISTANCE APPARATUS—POTENTIOMETERS.

The firm makes a line of resistance-measuring apparatus under the name of "Everight" ohmmeters. These operate on the Wheatstone-bridge principle, with a single circular slide resistance having an index moving over a graduated scale. Ratio coils provide for several ranges, and a portable galvanometer is built in. These ohmmeters are made in four patterns, the first being provided with a hand magneto generator for various voltages from 100 to 1,000, the corresponding upper limit of measurement being 20 megohms to 1,000 megohms, with a lower limit of 10,000 ohms in all cases. The next instrument of the series is operated by a battery, either self-contained or separate, which gives from 3 to 4 volts; the ratio coils are 5 in

[1] The following, from the firm's catalogue, is worth quoting at this point: "Owing to the word 'recording' being applied both to instruments which record on a chart and also to instruments which record on a train of dials, we have, in order to avoid confusion, described the former as 'graphic' instruments and the latter as 'integrating' instruments, and we think that the difficulties may possibly disappear."

number, and the total range of measurement is from 0.1 ohm to 11,000 ohms. The third instrument combines the ranges of the two preceding; the fourth is constructed on a modification of the Kelvin double-bridge principle, and has a range of 0.001 to 1 ohm.

The Everett-Edgcumbe portable potentiometer is intended especially for factory and central-station use. Electrically, it consists of 14 equal coils, with a slide wire whose resistance is equal to that of one coil. The regulating rheostat, galvanometer, and standard cell are built in, the whole outfit being compact (11 by 7 by 9 inches).

PHOTOMETRIC AND MISCELLANEOUS APPARATUS.

Photometric apparatus made by the firm includes a standard photometer bench, with rotating lamp holders and other accessories; a workshop photometer at a very moderate price ($7.29) and three forms of portable photometer.

In the line of electric traction accessories the firm makes several specialties. One of these is a leakage indicator for trolley standards, which gives an audible signal in case a contact occurs between the trolley standard and the wire carried by it. The "overhead equipment tester" is an attachment to be clamped to the trolley pole, two light steel springs being carried in such position as to make contact with the span wire on each side of the trolley wire. A special moving-coil instrument and switches are connected to the springs and to ground through the trucks. With this equipment in place, defective insulators [1] can be located while the car is traveling at regular speed.

The tramway speed indicator is a combination of magneto generator belt-driven from the car axle, and a moving-coil voltmeter, marked to read miles per hour, at each end of the car. The rail-bond tester is constructed on a principle similar to that used in the firm's ohmmeters above described. Under the head of electric control apparatus may be mentioned protective relays for alternating-current circuits, to the design of which Mr. Edgcumbe [2] has given special attention.

The firm draws its supplies of material principally from English sources. It has so far made no attempt to market its product in the United States, chiefly on account of the high tariff.

EVERSHED & VIGNOLES (LTD.).

The Acton Lane works of Evershed & Vignoles (Ltd.) are located in Chiswick, a residential suburb of London. The present buildings were erected in 1903 and were up to the best practice at that time. The main workshop is a substantial one-story brick building with a saw-tooth roof having the glass to the north.

The arrangement of the machine tools is such that the raw material is received at one end of the shop, where the larger milling machines, presses, lathes, etc., are located. After receiving the heavier operations the material is passed to the middle for operations that can be performed with lighter lathes and drills. The parts pass finally to

[1] The Board of Trade regulations require each separate insulator to be tested not less frequently than once a month; defective insulators to be replaced at once.

[2] K. Edgcumbe, Electrical Review (London), vol. 69, pp. 126, 163, 233; July 28, Aug. 4 and 11, 1911.

the farther end of the shop for more delicate work and for final adjustment at the benches. Many of the vertical milling machines are of American manufacture (Becker) and are well liked by the firm. Pratt & Whitney turret lathes are also in use.

MAIN BUILDING—CARD SYSTEM.

The main building is a two-story brick structure adjoining the main workshop. It contains the stores, adjusting rooms, and winding room. The arrangement of the stores is a very convenient one and is the outcome of careful study of this important feature of manufacture. Each rack or bin has a receptacle for a number of cards, upon which entries are made of materials or parts placed in the bin and of quantities removed, with the shop order number. Thus at any time the balance as shown on the card gives the amount of material which should be in the bin. At inventory time the cards are taken to the office for stock taking. A further feature of this card record is the color scheme, one color denoting raw material, another finished parts, etc.

Adjoining the main building is a calibrating room, with battery house. Large storage cells provide currents up to 8,000 amperes for testing heavy shunts; smaller cells provide the steady voltage necessary for voltmeter testing.

THE POWER PLANT—LABOR AND MATERIALS.

The power plant is located in a separate building. Formerly the dynamos were driven by two gas engines supplied with town gas. In December, 1911, a large oil engine was installed in place of one of the gas engines. The oil engine will hereafter do the work and the gas engine will be held in reserve. The offices, drafting, and design departments are in a separate building.

The company has about 300 employees, of whom about 50 are girls employed in the winding room. Under normal conditions 50 hours constitute a week's work. The average employee receives about 1 shilling (24.3 cents) an hour. The men are organized, but the company has not suffered from strikes or other evidences of discontent among the workers. The company draws its supplies of material from English sources, and a member of the firm expressed the opinion that the American producer could not compete with English sources of supply under present conditions.

SPECIAL PRODUCTS.

The company's principal product at one time consisted of indicating electrical instruments, such as ammeters, voltmeters, etc. While these are still manufactured, in recent years this line has been rather overshadowed by two somewhat special lines, in connection with which the company has secured an international market and reputation. The first includes ships' telegraphs, stoking indicators for use in ships' boiler rooms, and turret danger signals for giving warning to ships' gunners when the fire from the guns of their turrets would endanger other turrets or the muzzles of other guns. The limitations of the present article allow of only this reference to these

interesting instruments, which have been worked out with great skill to secure the reliability so vital in such apparatus, which must work under unfavorable conditions of shock, exposure to sea air, etc. The other special line is that of direct-reading portable apparatus for the measurement of resistance, and includes instruments known as the "megger" testing set and the "ducter" potential ohmmeter.

THE MEGGER TESTING SET.

The megger testing set consists of a moving-coil ohmmeter combined in one case with a magneto generator, the latter being wound to give as high as 1,000 volts in some patterns. The idea is to provide a portable apparatus which can be operated by an ordinary workman and which will give by direct indication in a few seconds the value of an unknown resistance. As the name indicates, the megger is especially adapted to measure high resistances, the upper reading of the scale corresponding to from 10 to 2,000 megohms in the stock patterns. A great advantage of instruments of this kind is that they determine insulation resistance with the working voltage applied to the object under test.

The details of construction of the megger have been worked out very carefully, as may be realized from the fact that the whole instrument, including the ohmmeter, the high-voltage generator with its commutators and carbon brushes, and the gearing with its constant-speed clutch, is sealed at the factory and is sold under a five years' guaranty.

A special modification, the "bridge megger," has a master switch to enable it to operate either as an ordinary megger or in conjunction with an external resistance box as a Wheatstone bridge; in the latter case the moving-coil instrument is used as a galvanometer. This allows of accurate measurements of resistances from 1 ohm to 10,000 ohms; however, the possible limits of measurements are much greater.

THE DUCTER TESTING SET.

The Wheatstone-bridge method, even in the laboratory, fails to give accurate results for very low resistances. However, it is necessary that methods be provided for the measurement of such important low resistances as those of switch contacts, rail sections, test pieces of cast or drawn metals or alloys, fuses, circuit-breaker coils, etc. In the laboratory this need is met by the use of the Kelvin double bridge and similar methods, and with care a very high accuracy can be obtained. For engineering and commercial work, however, high accuracy is wholly unnecessary, and the complications and refinements of the laboratory can not be practiced by the ordinary workman. What is needed is a simple method which gives moderate accuracy (5 per cent is ample in many cases), combined with portability, simplicity, and quickness of operation. To meet this need Evershed & Vignoles (Ltd.) have recently brought out the "ducter," which is based on principles similar to those used in the megger.

The ducter is a low-resistance ohmmeter having two moving coils rigidly attached to each other and moving in the field of a permanent magnet. An auxiliary two-volt storage cell passes a current through a suitable shunt within the instrument and through the unknown

resistance. One of the moving coils is connected in series with a resistance coil, and this "control circuit" is connected across the shunt. Since connections to the moving system are made by very thin spirals of the smallest possible torsion, the controlling force is practically proportional to the current flowing through the circuit whose resistance is to be measured. Potential terminals are placed on this circuit at the points between which the resistance is to be measured, and these points connect by flexible conductors to the second moving coil. The deflecting force thus varies as the resistance of the circuit between the potential points. By the use of 3 shunts and graded resistances in the control circuit the ductor is given 5 ranges. The first range is direct reading 0 to 500 microhms; one can read by estimation to the nearest microhm. The other 4 ranges are direct reading, except for the necessity of using the factors 10, 100, 1,000, or 10,000. The highest value measured with the ducter is thus 5 ohms. Accessories are furnished with the ducter to enable the specific resistance of samples to be measured without calculation. The ducter and the series of meggers have an enormous combined range, namely, from a full-scale reading corresponding to 0.0005 ohms to full-scale reading for 2,000,000,000 ohms.

THE DIONIC WATER TESTER.

The "dionic water tester" of Digby & Biggs is virtually a megger used to determine the specific resistance of a sample of water. The water is contained in a glass U tube, in each side of which is immersed a platinum electrode whose area is sufficiently large to prevent appreciable error due to the formation of gas bubbles. A mean value of the polarization electromotive force is allowed for in the calibration of the apparatus; since the dynamo voltage is 100, small variations of the polarization electromotive force do not introduce appreciable error. The scale of the ohmmeter (which is built in with the generator) is graduated in conductivity units for which at present no simple name exists; one such unit is the reciprocal of a megohm (which might be called a micromho[1]) per centimeter cube.

The conductivity of very pure water is exceedingly low; even small traces of impurity, however, will greatly increase the conductivity. A striking experiment witnessed by the writer will illustrate this. From a beaker of very pure water a sample was poured into the U tube; on turning the generator handle the needle of the ohmmeter showed that the conductivity was about 1.5 units. The thumb and forefinger were then rubbed together for a moment in the water remaining in the beaker. A sample of this water now showed by test a conductivity five times as great.

The dionic tester thus enables the user to detect very small traces of impurity in water; in the case of dilute solutions of a known salt, the amount of salt present per unit of volume can be determined. The dionic tester is applicable to the measurement of the hardness of water, thus enabling rapid checks to be made of the operation of water-softening plants. It may be used for detecting leakage in surface condensers by periodically testing samples of water from the

[1] This word would perhaps be objectionable in practice on account of its similarity to "microhm."

hot well; leaks may thus be discovered and repaired before they become serious. With the condenser in good order, boiler priming may be detected and measured. Other applications of the dionic tester are the detection of the pollution of streams and the checking of the operation of sewage-purification works. Many other applications will doubtless be found as the instrument becomes better known.

FERRANTI (LTD.).

BUILDINGS AND EQUIPMENT—EMPLOYEES.

The electrical engineering works of Messrs. Ferranti (Ltd.) are located in Hollinwood, a suburb of Manchester. The present company was incorporated in 1891, but Ferranti apparatus dates back much further, S. Z. de Ferranti being one of the pioneers in electrical development.

The buildings are of brick and are lighted by windows and from the roof. The machine tools are arranged along the main walls, and are group-driven by 220-volt direct-current motors and line shafting. The firm buys electrical energy, in the form of 3-phase 6,000-volt current, from the local lighting company, and converts it to direct current for distribution about the works.

About half the machines are English and half American. The latter are mainly automatic machines and small turret lathes, of both of which the company has a large number in use. The conditions under which the machines work are severe, in that they are run night and day. A number of heavy Cleveland automatics are working on mild-steel rods about 1 inch in diameter, and have been run night and day for the last three years. The American machine tools are well liked.

The firm's employees number about 1,700, of whom about 60 per cent are engaged in the manufacture of electric meters and instruments. Practically no female labor is employed, the reason assigned being that the neighboring textile mills employ all that is available, at wages greater than can be paid for electrical work. Boys wind coils, run turret lathes, and do assembling, testing, and adjusting. The working week consists of 52½ hours, the single-break system being used. Labor unions are recognized and union wages are paid. There has been practically an entire absence of strikes during the last 10 years.

DIRECT-CURRENT METER, MERCURY TYPE.

The products of the company include transformers, switchboard and control apparatus, electric meters and instruments, and electric heating and cooking apparatus. By far the most important item is that of meters, of which the company is making about 10,000 per month, about half of this number being for direct current.

The Ferranti direct-current meter, Hamilton patent, is of the mercury type. The company admits that good accuracy may be obtained from commutator meters when in good condition, but claims that this accuracy is soon lost in service on account of increase of brush friction and deterioration of brush contacts. They state that their 20 years' experience with mercury motor meters has enabled them to

overcome the difficulties attending the use of mercury, and in proof of this they cite the fact that their meters have been adopted by all the large supply companies of England after severe and extended tests. Their mercury meter as made for service use is an ampere-hour meter, the dials being marked to read Board of Trade units (kilowatt hours) at a stated voltage.

In this meter the copper disk is immersed in mercury in a chamber composed of nickel-plated brass top and bottom plates bolted together with a separating ring of fiber or hard rubber; the inner surfaces of the brass plates being further protected by press-pan sheet insulation. Into each brass plate are riveted two mild-steel pole pieces, to which strong permanent magnets are attached. The current enters the mercury by the contact at the right, flows radially across the disk between the right-hand pair of pole pieces, leaves the bath at the central contact, and flows through a compounding coil of a few turns wound on a mild-steel crossbar joining the two bottom pole pieces, which are of like polarity. The disk is caused to rotate by the interaction of the current flowing through it and the magnetic field between the right-hand pole pieces. Both pairs of pole pieces induce eddy currents in the disk, and furnish the necessary drag to make the speed of the meter proportional to the current. However, the variation of mercury friction is such that if the compounding coil were not used the meter would be slower the heavier the load. The current is passed through the compounding coil in such a direction that, as the current increases, the right-hand (driving) field is strengthened and the left-hand weakened. This makes the driving force greater than it would otherwise be, but leaves the braking force for a given speed unchanged, since both fields contribute to this, and one is strengthened and the other weakened by practically the same amount.

The copper disk is platinum plated and enameled to protect it from the mercury; the edge and center are left unplated, and are amalgamated in order to make good contact with the mercury. The mercury is purified very carefully, a detail which experience has shown to be quite necessary for good results.

The spindle that carries the disk is of nonrusting alloy. The worm is milled in this spindle by a specially designed machine. A steel pivot is inserted at each end of the spindle, each pivot being carried in a replaceable sapphire jewel. The mechanical balance of the rotating system is adjusted by three small nuts, and a weight carried by the spindle causes the whole system just to sink when the mercury is at the normal level. A sealing device, which contains no rubber or other perishable material, is used to prevent escape of mercury when the meter is to be carried about or shipped.

The case is of cast iron enameled inside and out after a careful cleaning to avoid trouble due to iron particles or grit entering the working parts when in service. Substantial cast-iron cases are preferred in England as a rule, and the head of the meter department of a large Italian company expressed his strong preference for such cases because of their ability to stand the rough handling of the class of labor used for carrying meters and placing them in position. The joint between cover and case is made with a gasket, and is said to be dust proof and water-tight. The carrying handle is useful for meters with cast-iron cases; it is a feature that has evidently been consid-

ered unnecessary by American manufacturers. Above 50 amperes shunted meters are used. Special cases are used having a compartment at the back for the shunt, so that the whole is self-contained. The starting current of these meters is given by the maker as from 0.03 ampere for a 1.5-ampere meter to 2 amperes for the 1,200-ampere meter. The drop at full load is about 80 millivolts.

CYCLOMETER DIALS.

While some forms of cyclometer dials have been found to be open to serious objection, Messrs. Ferranti consider the type made by them fully as reliable as the clock dial. The early cyclometer dials were, as the name indicates, simply adaptations of the familiar bicycle cyclometer. They had the defect of putting a variable friction load on the meter that became greater as more and more numbers had to be moved; as the higher wheels were idle for long periods, opportunity for corrosion and sticking was present. The friction to be overcome in turning several numbers at once is said to have been at times great enough to stop the meter. Such a dial mechanism is still used by some makers, but is especially objectionable in view of the reduced current consumption of metal-filament as compared with carbon lamps.

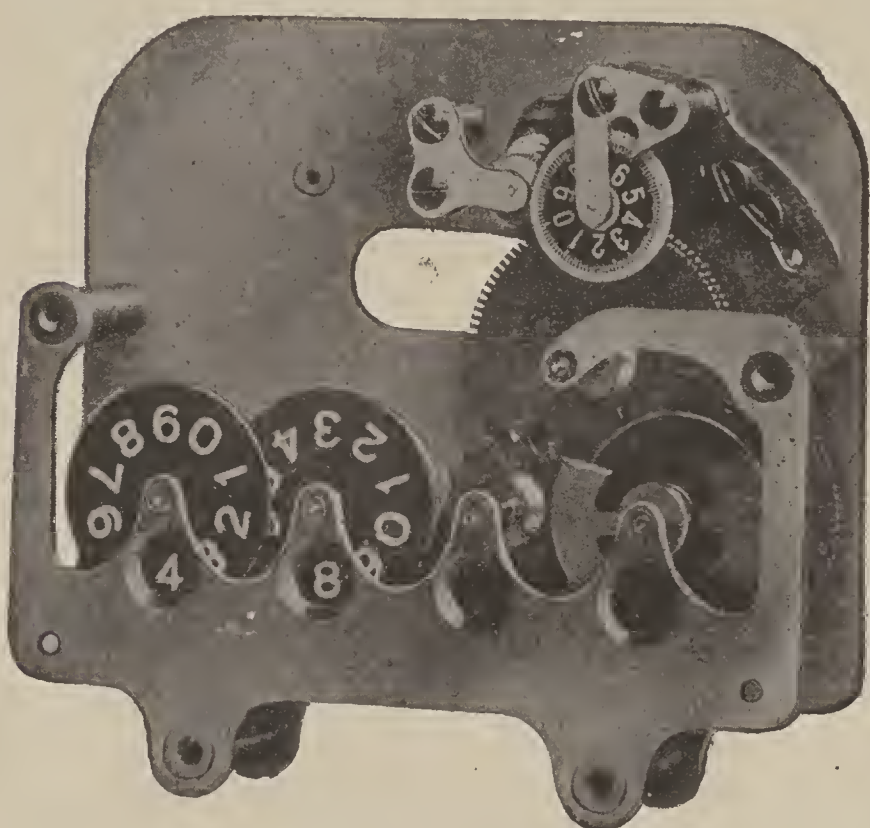

FIG. 1.—Ferranti cyclometer dial.

The firm states that the patent device used in its cyclometer dial avoids this difficulty. This device is shown in figure 1. A weight, partly counterbalanced, is carried on the spindle immediately over the number hole farthest to the right. This weight is slowly raised by the revolution of the spindle until it is just past its top position, when it falls suddenly, changing the figures definitely from one reading to another reading one unit higher. The weight is sufficient to change all the figures at once.

To facilitate testing, a small circle and pointer are provided on the dial, each division being one-tenth of a unit shown by the lowest number wheel, and a similar dial, with white figures on a black ground, is arranged above the dial, each numbered division being one one-hundredth of a unit of the lowest number wheel, and being further subdivided into thousandths.

While the writer agrees in general with the ideas which have governed United States practice of late, namely, that meter dials should, for ordinary house sizes, read kilowatt hours on the lowest dial instead of tenths as in the past, and that dials should be kept free from

everything unnecessary that may distract the attention or cause error, he has always held that from the consumer's point of view a meter test by disk revolutions alone is not complete, but needs to be supplemented by a check of the gearing ratio between the spindle and the lowest dial. This usually requires removing the dial from the meter, which gives opportunity for accidents to worm wheel or meter spindle. It might be well for American makers to consider the desirability of providing a tenths or hundredths dial to be used for testing purposes. To make this dial inconspicuous, it could be carried above the regular dial front, as is done in the Ferranti meter.

VARIOUS TYPES OF METERS.

The three-wire direct-current meter consists of two regular two-wire meter mechanisms contained in a single case, each indicating on a separate dial. These are made in sizes up to 150 amperes. The battery meter is similar to the three-wire meter, but each element is provided with a pawl to prevent backward rotation. One element indicates the total charge given to the battery, the other the total discharge.

The two-rate direct-current meter has the usual operating element, but with a double set of dials. An electromagnet is used to throw into gear the upper or the lower dial; this magnet is wound with fine wire and connected, with a suitable resistance, in a shunt circuit across the line. A time switch is used to close this circuit during the part of the 24 hours that the high rate is in effect. This time switch may be used to operate the magnets of a number of meters. The shunt circuit of each meter requires about 17 milliamperes; this is flowing only during the time the high rate is in effect.

Prepayment meters are made for direct and also for alternating current. The meter element is of the standard type and shows the total consumption on the usual cyclometer dial. The prepayment dial shows the total coins deposited up to 999, and the coins unused up to 12. The knife switch has a quick double break with an arcing distance of 1¼ inches. The customer in rotating the handle to introduce the first coin closes the switch and also raises a weight that is later released by the meter and opens the switch. The meter acts on the release action through a train of wheels geared down 55 to 1 to reduce the frictional load on the meter. These meters are made in 3, 5, and 10 ampere ranges, the weight being 25 pounds.

The traction meter is a modification of the regular direct-current type, the changes introduced being as follows: The bottom jewel is spring supported; an ordinary bearing is used at the upper end of the spindle in place of the usual jewel; the pivots are stronger, and the bottom one is rounded to a larger radius; the rotor is very light, and the meter is heavily shunted. It is said to be capable of standing 100 per cent overload for 10 minutes, and is guaranteed accurate within 2½ per cent from 10 per cent to full load.[1]

[1] The following note from Daily Consular and Trade Reports of Oct. 24, 1910, refers to the saving which may be made by using meters on street railway cars: "The British Tramways and Light Railways Association prints interesting information relating to the economy in current consumption in Continental towns as the result of the adoption of car meters, the highest saving recorded being over $100,000 a year by the Berlin company, which has 1,500 cars. There is still on the Continent some preference for the time meter, which simply shows how long current has been in use. In England the ampere-hour meter looks more likely to retain general favor. Berlin, Amsterdam, Cologne, and other cities claim that the hour meter is simpler, cheaper in first cost and maintenance, and better understood by the drivers.

INDUCTION METERS.

Before describing the modern induction meter, the manufacture of which has recently been taken up by the company, it will be of interest to describe the older form, which is still manufactured and of which many thousands are in service.

The series winding is wound in four coils on a cast-iron stator; below this are the mild-steel shunt core with two cast-iron polar projections, the shunt coil, and a cast-iron tube with screw for holding the shunt core in place. The use of cast iron and solid steel for these portions of an alternating-current meter is rather startling to one who is accustomed to the more common practice of using laminated magnetic circuits; in spite of this, the performance, as given by the maker's curves, is a good one. The torque is given as 20 millimeter grams, and the weight of moving element 23 grams. The full-load speed (for all capacities) is 40 revolutions per minute. The case is of cast iron, as in the direct-current meter. The same type is also made as a three-wire meter, the current winding having two strands. The shunt loss of the preceding meters is given as 2 watts for voltages up to 250 and 4 watts above this to 500 volts, both at 50 cycles. The drop in series coil of the 10-ampere single-phase meter is given as 0.15 volt, and inversely proportional to the current for other sizes between 3 amperes and 25 amperes; above 25 amperes the drop is somewhat greater than this formula would give. The starting current is given as about 1 per cent for 3 and 5 ampere sizes, 0.5 per cent for 10 to 25 ampere, inclusive, and 0.25 per cent for 50 to 100 ampere meters, inclusive.

The polyphase meter has two driving elements, as just described, working at diametrically opposite positions on a larger aluminum disk. The moving system weighs 45 grams, and the torque is given as 70 millimeter-grams. The speed with both elements at full load is 40 revolutions per minute. The figures given for shunt loss and series coil drop of single-phase meters apply, with the proper modifications, to polyphase meters.

The Ferranti "Type C" induction watt-hour meters embody the features of construction and operation that characterize modern induction meters. The disk is of aluminum, and the full-load speed is 40 revolutions per minute. The full-load torque is given as 50 millimeter-grams, and the weight of the moving element is 27 grams. The shunt loss is given at 1.5 watts; series loss up to 25 amperes capacity, 1 watt; the starting current of the 5-ampere size, 0.03 ampere. The weight up to 25 amperes capacity is 10.5 pounds with sheet-steel cover, or 11 pounds with glass covers.

The company obtains its supplies and materials from England, France, and Germany and markets its products all over the world, with the exception of the United States, where the high tariff makes competition with American products impossible.

NALDER BROS. & THOMPSON (LTD.).

ORGANIZATION, BUILDINGS, AND EQUIPMENT.

The firm of Nalder Bros. & Thompson (Ltd.) was established by F. H. Nalder and H. Nalder in 1884 as Nalder Bros. C. W. S. Crawley joined them in 1886, the name of the firm being changed to Nalder

Bros. & Co. Alfred Soames also joined the firm a little later. In 1896, the business having increased greatly, it was divided; the ammeter, voltmeter, and switchboard business was taken over by F. H. Nalder and E. Thompson under the name of Nalder Bros. & Thompson. In 1899 the business was converted into a limited liability company, and an additional factory building was secured at Dalston, in the northern part of London.

The principal office is located at 34 Queen Street, in the east-central district of London. Here also the work of coil winding, assembly, and testing of instruments is carried on, the work occupying several floors of the building. The factory at Dalston produces parts for stock, which are assembled at the Queen Street works. The Dalston factory is a three-story brick building, and is well equipped with machine tools, including full-automatic screw machines, ordinary turret lathes, engine lathes, milling machines, tapping machines, grinders, and drills. Included in the above are machines by Brown & Sharpe; Pratt & Whitney; Cincinnati Milling Machine Co.; Brainard Milling Machine Co.; Dwight Slate Machine Co.; Washburn Shops of the Worcester Polytechnic Institute; Hendey Machine Co.; and other American firms. The machines are driven by a gas engine through the usual line and counter shafting. The exhaust from this engine is carried up to the top floor and used to heat the plating baths before it escapes into the atmosphere. Gas furnaces are used for hardening, tempering, melting solder, etc. The temperatures for hardening and tempering magnets are determined by thermocouple and millivoltmeter. After being magnetized, the magnets are artificially aged and also numbered, tested, and marked with the strength, in arbitrary shop units. They are then stored for a period of time and again tested before assembly.

An interesting method of speed variation is used in the coil-winding machines at the Queen Street works. The spindle carrying the coil to be wound is driven by a small pulley, which is in contact with a special friction disk mounted on the shaft of an ordinary fan motor from which the blades have been removed. The friction disk has a spherical surface, whose center is in a vertical line through the center of the base of the motor; the motor is arranged to swivel about this vertical axis by pressure on a treadle. The arrangement is similar to that used in friction disk drills; it gives quick control of the speed of winding over the whole range from zero to maximum.

All instrument coils are dried in a vacuum, using an incandescent lamp as a heating element in the vacuum chamber. This practice has been followed by the firm since about 1888.

METHODS OF TESTING.

For alternating-current testing two alternators are driven by a direct-current motor. By varying the size of the driven pulley, frequencies from 25 to 100 can be obtained. Kelvin balances and Siemens electrodynamometers are used as standards for alternating-current testing. For the measurement of high voltages an arrangement due to Ayrton and Mather is used, consisting of a large number of coils in series, forming a high-resistance "volt box." Around a portion of this resistance is connected an electrostatic voltmeter reading up to 2,000 volts. The coils composing the high resistance

are mounted in a frame in such a way as to give high insulation and dielectric strength; taps are brought out at intervals, so that for various values of voltage applied to the total resistance, approximately full-scale deflection of the electrostatic voltmeter will be produced. The maximum current in the resistance coils is about 0.01 ampere. The maximum voltage measurable with this apparatus is 40,000; it is used for testing potential transformers and high-range electrostatic voltmeters.

For direct-current testing the potentiometer is used as ultimate standard, and portable instruments compared at intervals with the potentiometer are used as working standards.

CONDITIONS OF LABOR—PRODUCTS OF THE FIRM.

The number of employees is about 180; of these, about 15 to 20 per cent are girls. The hours of work are from 8 a. m. to 6.30 p. m. (with an hour for lunch at noon), except Saturday, when the works close at 1 o'clock.

The products of the firm include circuit breakers, switchboard and portable instruments, and instrument transformers.

Permanent-magnet moving-coil instruments for switchboard use are made in four sizes of round pattern, with dials from 5 to 11 inches in diameter, bases 6 to 12 inches in diameter. They are also made in four sizes of sector pattern, with scales 5 to 12 inches long, in addition to two older patterns still called for. The largest sector instrument has two movements astatically arranged; this construction reduces error due to stray magnetic fields and would seem to be very suitable for voltmeters. A number of forms of edgewise instruments are also supplied.. Ammeter shunt leads are provided at the shunt ends with strips of alloy several inches in length of the same material as is used for the shunts. The purpose of these strips is indicated by the name applied to them, "counterthermal electromotive force ends." Two types of portable moving-coil instruments are made; a "portable standard," with enameled metal cases of the sector form, and a "portable" at a lower price, in wooden case. Testing sets are also made, one form having a multi-range voltmeter and a millivoltmeter, the two movements being mounted in one case, and shunts being provided to give three or four ranges; the other form consists of a single moving-coil instrument provided with a change-over switch to enable it to serve either as a voltmeter or as a millivoltmeter, with shunts.

Soft-iron instruments are made on the repulsion principle, the iron used being specially treated to reduce hysteresis errors. This line includes two sizes of round pattern in iron cases, a smaller "gauge type" round pattern for use with motors, and a round-pattern instrument with a 3-inch dial. All the preceding are air-damped and are listed with gravity control, though spring control is supplied at an extra cost. Several sizes of round-pattern instruments in brass cases are still made to meet a demand for this form; these have gravity control and are undamped unless otherwise ordered. In addition, soft-iron instruments are made in several sizes of sector and of edgewise pattern, and also in the horizontal edgewise pattern familiar in the United States.

SWITCHBOARD WATTMETERS—ELECTROSTATIC VOLTMETERS.

A switchboard wattmeter (round pattern, 8-inch dial, 9.5-inch base) is made by the firm after designs by Dr. C. V. Drysdale. It differs from the usual forms in having a laminated iron magnetic circuit, around which is wound the series coil; the potential coil swings in a gap in the magnetic circuit. The use of iron greatly increases the torque, and thus makes possible the use of stronger control springs. It is stated that the instruments are accurate on low power factors and are free from error due to variation in frequency and wave form; also, that they are suitable for use with direct current, the hysteresis error being said to be practically negligible. These wattmeters have magnetic damping.

Electrostatic voltmeters for switchboard use are made with pivoted moving element, in round-pattern brass cases, with upper limits of 1,200 to 6,500 volts. A modified form of somewhat lower cost is made in practically the same ranges, in an iron case. In the brass-case form a neat device is used to make it safe to replace the self-contained fuses without disconnecting the line wires from the terminals. A hard-rubber block is attached to one end of a brass arm, the other end of the arm being hinged to the case. The hard-rubber block carries the terminals to which the line wires are attached; metallic extensions of these terminals enter insulated openings in the case, near the base, when the hinged arm is pushed down, and make contact with the ends of the removable fuses. By raising the arm the terminals are swung away from the case, and the fuses may be readily replaced.

RECORDING INSTRUMENTS—CURRENT TRANSFORMERS.

Recording instruments are made in the permanent-magnet moving-coil type, and also in the moving-iron type; both types are supplied in switchboard and in portable forms. The soft-iron type for switchboard use must be adjusted for a particular frequency, unless a special compensation for frequency, at extra cost, is ordered; it is stated that this compensation makes the instrument read correctly on any frequency, and also on direct current. All recorders are oil-damped, except portable recording voltmeters. Two forms of chart are used. The single-revolution chart is wound around a cylindrical drum, and must be replaced after one revolution of the latter, which is made in 6, 12, or 24 hours. The continuous-record chart consists of a roll of paper 63 feet long. The drum for the latter has a set of needle points on one side, which drive the paper forward; it is thus unnecessary to perforate one edge of the chart.

Current transformers are made in open type for use on circuits up to 2,500 volts and in inclosed (oil-immersed) type up to 12,000 volts. The open type has a wound primary coil up to 250 amperes; the bar type is supplied for 300 to 5,000 amperes. The standard secondary full-load current is 5 amperes. Potential transformers of the standard type are rated at 50 watts, 40 cycles, and give 110 volts on the secondary with rated primary voltage. Up to 2,500 volts the open type is supplied; above that, up to 12,000 volts, the oil-immersed type.

Other switchboard instruments made by the firm include ground detectors, moving-coil type, for mine use; round-pattern frequency meters, vibrating-reed type; round-pattern power-factor meters and synchronizers.

THE OHMER—MARKETS.

The ohmer (Cox's patent) is of interest on account of the principle involved. It consists of a pivoted electrostatic instrument whose operating parts consist of four sets of fixed quadrants, each set having 13 vanes, the space between adjacent vanes being about 0.2 inch, and a moving element consisting of 12 fishtail-shaped vanes of mica covered with aluminum. This construction is said to be much better than the one using solid aluminum vanes, the mica being much more elastic and not so readily deformed. A hand magneto generator wound for 500 or 1,000 volts is connected through a high resistance to the terminals to which unknown resistances are to be connected, and two sets of fixed quadrants are joined to each end of the high resistance. The moving vane is connected to the commutator brush which goes directly to one of the "unknown" terminals. When the resistance between these terminals is infinite there is no fall of potential along the resistance coil to whose ends the two groups of fixed quadrants are joined, so that these groups are at the same potential; the moving element will take up a position such that symmetrical portions of it are inclosed by the two groups of fixed quadrants. If the "unknown" terminals are joined by a wire of negligible resistance, the moving element will have the same potential as one of the fixed elements, and will turn until it is symmetrically inclosed by the other fixed element. For values of resistance across the unknown terminals intermediate between zero and infinity, the moving element will take up intermediate positions, and the scale may be graduated by trial. The upper limits for which the instrument is made are 20, 50, and 100 megohms; each instrument has a switch for shunting the internal resistance down to one-tenth of its value, so as to reduce the range in the same proportion. The 1,000-volt ohmer may be fitted with two vibrating reeds under the window opening of the instrument. One of these reeds will be set in vibration when the speed is that which generates an electromotive force of 500 volts; the other reed responds when the electromotive force is 1,000 volts.

The ohmer is independent of voltage, in principle; in practice this depends upon the ratio of the actuating torque, for a given displacement of the moving element from its true position, to the torque of the flexible conductor used to make connection with the moving element, and also to the frictional torque. The latter is a difficulty in the way of making satisfactory pivoted electrostatic instruments; in the present instrument the ohmmeter and the generator are mounted on the same base, and the vibration transmitted from the generator tends to prevent frictional errors. The prominent advantages of the instrument are the lightness of the electrostatic ohmmeter as compared with permanent-magnet moving-coil ohmmeters, and its independence of stray magnetic fields.

The firm uses British materials almost exclusively. Its product is marketed in Great Britain, Canada, English colonies, and abroad generally, but very little is sold in the United States on account of the high duty.

ROBERT W. PAUL.

BUILDINGS AND EQUIPMENT.

The Newton Avenue works of Robert W. Paul are located at New Southgate, one of the northern suburbs of London. The business was established in the city of London by Mr. Paul in 1891, and the present works were erected in 1902–3.

There are four buildings in all, with a total floor space of about 20,000 square feet. All are of brick, and were planned especially for instrument manufacture. One two-story portion of the main building contains, on the ground floor, the drawing and other offices, storerooms for materials and finished apparatus, and the room where apparatus is inspected before shipment. The floor above is divided into five rooms, which are equipped for the winding of galvanometer coils and of resistance coils, and for the testing and adjustment of resistance apparatus, galvanometers, millivoltmeters, inductance apparatus, etc. The other two-story portion of the main building contains the power plant and storage batteries. The prime mover is a gas engine operated on producer gas; it drives the machine shop by means of a line shaft, and also two direct-current dynamos used for battery charging. In addition to a battery giving a usual lighting voltage, several large cells are provided for heavy currents at low voltages, a special low-voltage generator being provided for charging them. A motor-generator set is provided for supplying alternating currents, and may be operated from the engine-driven generator, or, when steadiness is essential, from the storage battery.

The one-story portion of the main building is the main workshop; it has a saw-toothed roof. The equipment includes, in addition to the usual bench and engine lathes, turret lathes, milling machines, drills, sheet-metal working tools, and machines for grinding, gear cutting, engraving, etc. Included in the above are several machines of American make.

An interesting feature of the assembly benches in the main workshop is the provision for securing increased bench room at times by swinging unused bench lathes back against the wall. The countershaft for each lathe is on the top of the bench close to the wall; it has a cast-iron arm that swings in a vertical plane perpendicular to the wall, about the axis of rotation of the shaft, and carries the lathe at its outer end. Thus the lathe may be swung back at any time without removing the belt or changing its tension. Opposite the assembly benches are the lighter engine lathes, small drills, milling machines, and shapers.

A complete duplicate set of standard parts is kept on racks in the drawing office, where they are often referred to in designing new apparatus. One sample of each pair has a red tag attached. This sample is available for mailing to makers of standard parts, for quotation, or for supply. The other sample bears a green tag and is not allowed to leave the works.

TESTING MICROAMMETERS.

A labor-saving device is used for calibrating microammeters, which are an important product of these works. A special dial rheostat has its resistance so adjusted that when a certain standard

amount of additional resistance is in series with it, and an electromotive force of 0.1 volt is applied to the resulting circuit, currents of five, ten, fifteen, etc., hundred-thousandths of an ampere will flow for the successive positions of the dial. The current is supplied by a small storage cell, the dial rheostat and external resistance being tapped off from about one-twentieth of a resistance connected across the cell. A simple one-point potentiometer arrangement enables the standard drop of 0.1 volt to be maintained by the occasional adjustment of a slide rheostat. The value of the external resistance used in series with the dial rheostat is greater than the resistance of any microammeter to be tested, and hence the external resistance may be reduced by an amount equal to the resistance of the particular microammeter under test. Therefore no error is caused by the resistance of the microammeter. This arrangement may be extended, when the nature of the product demands it, by having other points on the potentiometer arrangement, so that standard potential drops of higher or lower values may be had and checked against the standard cell.

MAGNETIC PURITY OF MATERIALS.

For testing the magnetic purity of samples of insulated wire, coil frames, and fittings, as used in the construction of galvanometers, an apparatus is used based on a similar apparatus described by Madame Curie. This apparatus contains a long phosphor-bronze suspension strip, as used in moving-coil galvanometers. The lower end of the strip carries a horizontal "boom," consisting of a brass wire about 8 inches long. One end of the boom carries a sector-shaped sheet of copper, which moves in the jaws of a strong damping magnet; the sample of material to be tested is hung from the other end of the boom, being slid along to such a position as will make it balance the weight of the damping disk and bring the boom to the horizontal position. A second damping magnet, with vertical air gap, is brought into position so that the sample under test hangs freely in its gap. This second magnet is carried on a support that is pivoted at a point below the suspension and in line with the latter; the support may be slowly rotated from without when the glass sides of the case are in place to screen the system from air currents. If there are magnetic impurities in the sample, it will be dragged along by the magnetic field until the torque of the twisted suspension is greater than that due to the magnetic attraction, when the coil will swing free from the magnetic field. A galvanometer mirror is carried on the suspension; by means of a lamp and scale, the magnitude of the deflection from the initial position may be read. It is not necessary to reduce the result to absolute units of any sort, as the relative behavior of various lots of materials and the permissible limit of magnetic impurity may be determined by experience.

SPECIAL APPARATUS FOR MAKING INSTRUMENT SCALES.

All instrument scales are especially made to suit the individual instruments. To do this work accurately and quickly, Mr. Paul devised and built special apparatus. This consists of two principal mechanisms. The instrument to be "scaled" is placed in the first

one, and as the successive values of current are passed through it a radial arm (pivoted to rotate about a vertical line passing through the axis of rotation of the coil) is swung around so that the image of the instrument pointer is brought under the cross wire of a reading microscope carried on the radial arm. A stylus carried at the end of the radial arm is then depressed, making a pinhole in a paper chart; these pinholes are on an arc of a circle several times as large as the arc described by the end of the instrument pointer. By repeating this operation a chart is obtained which is really a scale to fit the law of the instrument, but magnified several times. This chart is marked with the serial number of the instrument and the range and figuring desired and sent to the scale-making room. Here it is put in the proper position in the second apparatus, which has a pointer carried at the end of a radial arm swinging about a pivot. A blank scale cemented to its supporting plate is then put under the radial arm, guide pins bringing it into the correct position. The radial arm carries a printing attachment, which may be provided with type for printing lines of various weights. The printing attachment is self-inking and automatically makes the changes in length of the fifth and tenth division lines. It is also possible to print either horizontal or vertical scales.

LABOR CONDITIONS.

The number of employees is about 85, of whom about 10 per cent are girls. These latter do the coil winding, scale making, and similar light work. The number of hours per week is 50 for the workshop, 44 to 48 for the testing department, and 48 for apprentices, who are allowed time off to attend evening classes. The average rate of pay for daywork is, for journeyman instrument makers, 18 to 20 cents per hour; for piecework, 24 to 28 cents per hour. No trouble from strikes has been experienced.

TYPES OF RESISTANCE APPARATUS MANUFACTURED.

The types of resistance apparatus made by Mr. Paul include single-value standards, dial and plug boxes, Wheatstone and slide-wire bridges. Single standards of Reichsanstalt type are wound with manganin wire. The Drysdale compensated resistance standard is made with the object of securing great permanency combined with small temperature coefficient. With the first-named requirement in mind, all perishable organic substances (silk and varnish) commonly used in such standards have been avoided by the use of bare wire wound on porcelain supports. (A similar construction was proposed by Prof. F. W. Burstall and is described in the Proceedings of the Physical Society of London, vol. 14, p. 286.) To secure the smallest possible temperature coefficient, a constantan wire, whose resistance decreases slightly with increasing temperature, is plated with such a coating of nickel (whose resistance increases with increasing temperature) as will most nearly compensate the two opposing effects. If both metals had a linear variation of resistance with temperature it would be theoretically possible to secure perfect compensation. As both constantan and nickel depart somewhat from a linear variation (in opposite directions), this is not possible.

These coils are listed by Mr. Paul in three denominations, namely, 1, 10, and 100 ohms. A question that will naturally arise is, Will not such coils be more troublesome to work with than manganin coils, on account of the large thermal electromotive force of constantan in contact with copper? For the 10 and 100 ohm coils this would probably not be of consequence; for 1-ohm coils and lower values it would seem possible to apply the same principle by nickel plating manganin which has been selected for negative temperature coefficient. This would avoid the thermoelectric difficulty. The temperature coefficient of magnanin is commonly given as positive, but varies considerably in different samples, and is sometimes negative. The temperature coefficient of a sample of manganin may be appreciably changed by annealing it.

For resistance substandards of 0.1 per cent accuracy, and for standard types of plug and dial decade resistance boxes and bridges, Mr. Paul uses eureka alloy, though manganin is supplied if required, at an extra cost.

The "precision decade resistance," made according to designs of A. C. Jolley, is an arrangement of manganin coils in a metal case for oil immersion, with some novel features of construction. The coils are wound on large brass tubes slit lengthwise to insure a certain amount of yielding, and covered with thin micanite tubes in place of the usual silk. Each decade of coils is mounted in a metal framework, with mica-insulated segments on the upper surface. This dial has the coils soldered to the segments and may be lifted out, since no connecting wires are used between the dials. Instead, a laminated copper brush is pivoted to make yielding contact, one end with the central ring of one decade, the other end with the segments of the next decade. Each dial is rotated by a crank, the set of coils revolving under the fixed brush. Because of the large size of the coils, and the oil cooling, these coils will carry considerably greater currents than the usual small air-cooled coils. A click device is used to indicate to the sense of touch when the dial is central in each contact position.

Another line of decade boxes and bridges has stationary coils of eureka wire wound on porcelain spools, the coils being proportioned to give low capacity and inductance. The 10-ohm coil of this type is stated to have a resultant inductance of 3×10^{-7} henry. There are no live metal parts on the rubber top except the binding posts; the brushes and contacts are thus protected from dirt, and leakage is avoided.

In another line of resistance boxes, plug contacts are used, the blocks being molded in the hard-rubber top, so that the surfaces of blocks and top practically coincide. This construction is used to prevent shifting of the blocks, which sometimes occurs where the blocks are screwed and pinned on the top. The insulation resistance between adjacent blocks is stated to be 10,000 megohms.

Carbonized-cloth regulating rheostats, carbon-plate rheostats, rheostats for arc lamps, and other types are made for currents ranging from 1 to 500 amperes.

UNIPIVOT INSTRUMENTS.

The best-known instrument of Mr. Paul's manufacture is probably the "unipivot," made in both moving-coil (permanent-magnet) type

and electrodynamometer type. The distinguishing feature of these instruments is the use of a circular coil supported on a single pivot, the point of which is at the geometric center of the coil, and also at the center of gravity of the moving system. This construction allows the coil to swing freely without touching the core or pole pieces, and is said to give much less friction than the usual two-pivot construction; it also permits the raising of the pivot from the jewel for transportation. By using relatively light springs, the current sensitiveness of the unipivot instruments is made quite large; for example, a 350-ohm instrument with 150-division scale about 7 inches in length gives five divisions deflection per microampere; the time required for the index to come to rest, after closing the circuit, being about five seconds. If reduced sensitiveness is permissible, with a given coil resistance, the time can be reduced by using a stronger spring. The 10-ohm galvanometer of the same pattern as the preceding gives one division for 2 microamperes, or 20 microvolts on the coil. Unipivot galvanometers have printed scales, and are not adjusted to any exact value of current (or voltage) per division. Similar instruments are made with calibrated scales, as millivoltmeters, milliammeters, insulation meters, "universal sets" for measuring practically all direct-current quantities, and pyrometer indicators; the last are also made in horizontal edgewise pattern for mounting on walls. The "Ampall" is a portable unipivot moving-coil instrument giving full-scale deflection for 2 millivolts; a contact block is provided which has two potential points spaced at such a distance as will give a drop of 2 millivolts on a copper conductor 1 square inch in cross section carrying 1,000 amperes; the scale is figured from 0 to 1,000, and is thus direct reading for such a conductor. With smaller or larger conductors, the reading multiplied by the cross section of the conductor gives the current; this calculation may be quickly made by a circular slide rule supplied with the instrument. The same instrument may be used for conductivity tests, using a 20-microhm copper resistance forming part of the outfit.

Unipivot dynamometer instruments have the moving coil and pivot construction as in the permanent-magnet type. The moving coil is inclosed by the fixed coils. These instruments are made as milliammeters, giving full scale deflection for 20, 50, 100, or 1,000 milliamperes. With the addition of series resistance (free from inductance and capacity) these dynamometers are made as voltmeters, with resistance of 50 ohms per volt. Wattmeters are made on the same principle, the special feature being the low ranges possible.

HIGH-FREQUENCY AMMETER AND GALVANOMETER.

The Fleming high-frequency ammeter, as made by Mr. Paul, consists of a permanent-magnet unipivot instrument connected by flexible leads to a fine iron-eureka thermocouple which is located at the center of a copper wire carrying the current to be measured, or, if the latter exceeds 2.5 amperes, a portion of the current. The high-frequency galvanometer and the thermomilliammeter operate on the same principle; in the former, two wires (one iron, one eureka) are looped together at their centers, and held in X-form by springs; the high-frequency current to be measured enters on an iron terminal and leaves from a eureka terminal. The heating of the junction sets

up an electromotive force in the remaining thermojunction, across which the galvanometer is connected. A current of 1 ampere gives full scale deflection. The thermomilliammeter operates in a similar manner, but the thermojunction is in a vacuum; the ranges made are 0 to 10 and 0 to 20 milliamperes. These thermal instruments may be calibrated on direct current, since the wires carrying the current to be measured are small enough to keep the error from "skin effect" down to an amount negligible in practical work.

POTENTIOMETERS, REFLECTING GALVANOMETERS, AND WATTMETERS.

The slide potentiometer made by Mr. Paul is electrically one dial plus a slide wire. The coils forming the dial are mechanically arranged as two dials, one reading from zero up to about half the range, the other covering the remainder. The cadmium cell is provided for, and the working current may be checked by throwing over a double-pole switch, regardless of the dial and slide-wire positions. The long-range potentiometer, designed by Mr. S. W. Melsom, is electrically equivalent to one dial of 150 1-ohm coils plus a slide wire, but the 150 coils are mechanically distributed over a number of dials. The thermoelectric potentiometer (Carpenter-Stansfield) has two dials, the remaining figures of the result being read on the galvanometer scale.

Paul reflecting galvanometers are of the Ayrton-Mather type, and have a closed auxiliary damping winding in addition to the main coil. By opening the damping circuit the galvanometer may be made ready for ballistic work. The Campbell "standard galvanometer" is a moving-coil instrument for use as a precision ammeter or voltmeter in connection with suitable shunts and series resistances. To avoid spring fatigue, a wide bifilar suspension is used. The deflections are read by lamp or telescope and scale.

The Duddell-Mather standard wattmeter is a torsion-head instrument designed to avoid sources of error as far as possible. It is an astatic instrument, with stranded fixed coils that may be connected in various groupings to secure a wide total range. Metal parts are avoided to prevent eddy current errors; air damping is used. The design is such that full scale deflection can be obtained, without overloading the coils, at power factor 0.1. For use in the potential circuit of this wattmeter, an oil-immersed series resistance of the Duddell-Mather "gauze" type is used. This "gauze" is a fabric 7.5 inches wide, made of silk-covered eureka wire woven with silk threads. The construction gives low capacity and inductance, high insulation, and large cooling surface. A suitable length of the gauze is supported on porcelain insulators.

INDUCTANCE APPARATUS—THERMOCOUPLES.

Inductance apparatus made by Mr. Paul includes the Campbell variable mutual inductance; fixed self and mutual inductance standards; the Campbell "microphone hummer" for supplying small currents at 800, 1,000, 2,000, or 3,000 cycles; and the Campbell vibration galvanometer.

In addition to the pivoted and sector patterns of the Ayrton-Mather electrostatic voltmeters, Mr. Paul makes Ayrton-Mather

reflecting electrostatic voltmeters, with range of 1 to 9 or 4 to 30 volts; also a torsion-head pattern with range up to 60 volts.

Paul thermocouples are made with a rod of eureka alloy inclosed in an iron tube and insulated from the tube by steatite and magnesia, except at the end, where the iron and eureka are welded together to form the thermojunction. These are for use up to 900° C.; above this temperature, up to 1,600° C., a couple is used that consists of two wires of platinum-rhodium alloys of different percentages. These couples are said to be more durable and less liable to contamination than platinum-iridium couples. Unipivot indicators are used; for comparatively low ranges the indicator is fitted with the Darling compensator. This consists of a bar formed of two dissimilar metals, as used in thermostats and metallic thermometers, which is arranged to shift the zero reading of the indicator with changing room temperature by an amount such as will correct for the varying temperature of the "cold junction." Apparatus is also made for temperature measurement by the electrical resistance method, using the Harris direct-reading indicator. The latter is a permanent-magnet moving-coil ohmmeter, whose construction is such that moderate variations in the working current produce no perceptible effect on the readings; it may be operated by a 4-volt storage battery or from a direct-current lighting circuit. It is electrically equivalent to a differential galvanometer with a third winding at right angles to the other two, the third winding providing the controlling force.

HOT-WIRE OSCILLOGRAPH.

The Irwin hot-wire oscillograph is about the last application that one would expect to make of the hot-wire principle, as hot-wire instruments are notably sluggish in coming up to final reading for a given current. The results obtained are remarkable. (Journal of the Institution of Electrical Engineers (London), vol. 39, p. 617; 1907.) The principle of the instrument consists in using two fine wires under tension, carrying a light mirror; the wires are polarized by passing a direct current through them. The alternating current is then superposed on the direct, so that at any moment the direct current in one wire is increased and that in the other decreased. The mirror will thus be deflected to one side, the deflection being practically proportional to the instantaneous value of the current, neglecting thermal lag. The natural sluggishness of the hot wire, due to heat capacity, is overcome by modifying the current wave. For example, in using the hot-wire element in series with a high resistance to get the form of a voltage wave, a condenser is shunted around a part of the resistance. In order that the oscillograph shall give the true form of the voltage wave, the product of the capacity of the condenser and the resistance around which it is shunted must equal a constant which depends on the heat capacity of the wires and their rate of losing heat.

Mr. Paul secures his materials almost entirely from English sources; he stated that American dealers have not offered to supply him. His products are marketed throughout the world. While the high tariff tends to limit sales in the United States, he confidently expects to increase his sales there.

H. TINSLEY & CO.

The works of H. Tinsley & Co. are located at South Norwood, London, S. E. In addition to apparatus for submarine and wireless telegraph work, such as siphon recorders, paper condensers, and artificial line boxes, some electrical instruments of special types are made. It is of interest to note that telegraph condensers and artificial line boxes are adjusted in terms of the British Association microfarad, while for all other purposes the international microfarad is the unit employed.

UNIVERSAL POTENTIOMETER—STANDARD CELLS.

Tinsley's "universal potentiometer" for direct currents has for the highest dial 19 10-ohm coils in series. A double contact lever runs over the studs of this dial, the 2 contacts inclosing 2 coils of the dial and being joined to the ends of a series of 10 2-ohm coils, which constitute an electrical vernier to the first dial. One moving contact for the galvanometer runs on the second dial and the other moving contact runs over a straight platinum-silver slide wire about 15 inches long, divided into 115 divisions, each of which corresponds to 0.01 step on the second dial. The range of the potentiometer is thus from 0 to 1.81 volts, one division on the slide wire being 0.0001 volt. By shifting a plug, the current through the dials may be reduced to 0.1 the normal, lowering the range of the potentiometer in the same proportion.

Mr. Tinsley has made a specialty of Weston normal cells, which he makes in accordance with the specifications of the British National Physical Laboratory. In this cell a constriction is made in the limbs of the glass H tube. The crystals become caked and the constriction holds them in place, so that the cells can be shipped without suffering damage.

DRYSDALE WATTMETER.

The Drysdale double wattmeter is constructed with the intention of avoiding all sources of error and of giving flexibility in use. It is a torsion-head instrument and contains 2 moving coils mechanically coupled and 2 sets of fixed coils. The latter are wound with a cable made of 10 insulated strands. By means of a commutator these strands may be joined in various groupings, so as to give the full ampere turns for 1, 0.5, 0.2, and 0.1 the maximum current. The upper and lower systems are at right angles to each other to avoid mutual induction between them. The moving system is brought back to the zero position by turning the divided head, and in this position there is also no mutual inductance between the fixed coil and the moving coil of each system. Metal parts near the coils are avoided, the case of the instrument being of wood and glass, the screws and some other parts near the coils being made of ivoride. The 2 dynamometer systems may be used in series or in parallel on the same circuit or they may be used for the measurement of polyphase power. Single-phase power in one system may be balanced against direct-current power in the other, and various other special uses of the instrument are possible. The instrument is not astatic on direct current. The inductance of each moving coil is 1.5 millihenrys, and

the normal resistance of the potential circuit is 5,000 ohms for 100 volts, so that self-inductance errors are quite small at all ordinary frequencies.

ALTERNATING-CURRENT POTENTIOMETER.

The Drysdale alternating-current potentiometer consists of the combination of the Tinsley potentiometer for direct current, as above described, with accessory apparatus, namely, a Weston milliammeter of the electrodynamometer type, giving nearly full deflection for 50 milliamperes, and a phase shifter. The latter resembles an induction motor, the wound rotor being adjustable in angular position over a range of 180°. For single-phase supply, the stator is wound as for a 2-phase circuit, and a condenser is used to split the phase, and is adjusted so as to give a constant voltage in the rotor for any position of the latter. A pointer attached to the rotor has two scales, one reading in degrees of arc, the other in power factor.

In use, the potentiometer is first supplied with a current of 50 milliamperes from a storage cell, the current being adjusted in the usual way by reference to a standard cell. At the same time, the accuracy of the milliammeter in series with the potentiometer may be checked by taking the mean of two readings, the direction of the current through the milliammeter being reversed for the second reading. By a change-over switch, the potentiometer is now supplied with alternating current at 8 volts from the rotor of the phase shifter. This current is now brought to the same value (50 milliamperes) as determined by the reading of the milliammeter. Unknown electromotive forces may now be measured by the potentiometer, using a vibration galvanometer as the detector. Balance requires two things, namely, that the unknown electromotive force has the same magnitude as that included between the two traveling contacts for the galvanometer, and also that the two electromotive forces are in the same phase. The two adjustments are made by successive approximations, and are not difficult to carry out.

To secure accurate measurements with the alternating-current potentiometer it is necessary that the electromotive force of the supply circuit should approximate closely to a sinusoidal form. With such a supply the phase shifter is said to reproduce the primary wave form with the greatest harmonics due to distortion not exceeding 2 per cent, which introduces an error in the result which is practically negligible. The accuracy of the indications of the phase shifter is said to be within 0.1°. This potentiometer has certain limitations, namely, the accuracy of the result can not be greater than the accuracy with which the milliammeter measures the current through the potentiometer; secondly, currents which are distorted in comparison with the electromotive force causing them, such as the currents in circuits containing iron cores, can not be measured accurately. The reason for this latter condition is that the vibration galvanometer responds only to the sine component of the current through its coils, and hence if one attempts to measure, say, the current of a transformer whose secondary circuit is open, the reading of the potentiometer gives only the fundamental component of the magnetizing current, ignoring the large harmonics. In spite of these limitations, the alternating-current potentiometer is evidently a valuable research instrument for locating alternating currents and voltages, both in magnitude and phase, and it will

doubtless prove useful for educational purposes also. It is said that the potentiometer works well up to 1,000 cycles or more, and is now being used for the investigation of telephonic currents.

VIBRATION GALVANOMETER.

The Drysdale-Tinsley vibration galvanometer has a small soft-iron vane suspended between the poles of a permanent magnet and carrying a small mirror. The magnetizing coils are interchangeable, and the tuning is accomplished by sliding a piece of soft iron along the limbs of the magnet, thus varying the amount of magnetic shunting, and hence the strength of the field in which the iron vane moves. This method of tuning does not cause shift of zero.

FRANCE.

J. CARPENTIER.

The works of J. Carpentier, located at 20 Rue Delambre, Paris, produce a great variety of scientific apparatus, a large proportion of which consists of instruments for electrical and magnetic testing. In addition to resistance apparatus, inductances, condensers, galvanometers, magnetic testing apparatus, and other instruments more especially for the laboratory, switchboard and portable electrical instruments are made.

HOT-WIRE AND INTERCHANGEABLE-COIL WATTMETERS.

The hot-wire wattmeter has two working wires joined in series and connected in parallel with a current shunt which is inserted in one line of the two-wire circuit in which the power is to be measured. The point of junction of the two hot wires is connected through a series resistance to the other line wire. The difference of expansion of the two wires is proportional to the power in the circuit. By means of a switch, the connections may be changed so that the instrument reads volts; in a third position of the switch the current in amperes.

The portable precision wattmeter has interchangeable series coils, each mounted in a wooden block that is guided accurately into place and held firmly. It is said that by care in the design and winding of these field coils the scale will be correct for each, and the reading multiplied by the constant of the series coil in use gives the watts. The series coils are made for currents from 1 to 300 amperes. The same instrument may be used as an ammeter. In this case the current to be measured is passed through the series coil and through a noninductive shunt. The small difference of potential at the terminals of this shunt is transformed up and applied to the moving-coil circuit. By using a series coil of fine wire connected in series with the moving coil and its series resistance, the instrument becomes a voltmeter. Current, voltage, and power can be read successively by means of a special switch.

PHASE METER—AMMETER SHUNTS—OSCILLOGRAPH.

The Arno phase meter consists of two dynamometer instruments in one case, with their needles crossing. One instrument measures the watts in a circuit, the other the volt amperes, and the intersection of the two gives the phase angle.

Manganin is used as resistance material in ammeter shunts for switchboard and portable instruments. A convenient combination

shunt is made for use with a portable millivoltmeter. This consists of four shunts in series, one line terminal and one millivoltmeter terminal being connected to one end of the series. To the other end is connected the other millivoltmeter terminal. The second line terminal is connected by a slider to the junction points of shunts 1 and 2, 2 and 3, 3 and 4, or the end of shunt 4, thus changing from one range to another without opening the circuit or changing any connections. The general plan is that of the Ayrton-Mather universal shunt for galvanometers.

The Blondel oscillograph is made in two types, which differ only in the construction of the galvanometer. In one form the galvanometer has fixed coils acting to deflect a small piece of iron carrying a light mirror; in the other a fine bronze loop is stretched in a magnetic field and carries a mirror.

PYROMETERS—MOVING-IRON INSTRUMENTS—FREQUENCY METER.

Pyrometric apparatus is made on the thermoelectric and the resistance principle. Féry radiation pyrometers are also made. Moving-iron ammeters and voltmeters are made on the repulsion principle and have air damping. The Ferrié-Carpentier frequency meter consists of two hot-wire milliammeters. One of these in series with an inductive coil is paralleled with the other plus a noninductive coil; the parallel circuit so formed is connected in series with a resistance across the line whose frequency is to be measured. The frequency is read off from the point of crossing of the two pointers. The Ferrié-Carpentier ohmmeter is constructed on a similar plan. The Abraham frequency meter has a single system and pointer. A moving coil is pivoted in the field of an electromagnet, current being led into and out of the coil by silver strips of negligible torsion. A small noninductive resistance is in series with the electromagnet; the moving-coil circuit is connected to the ends of this resistance and includes the secondary of a small transformer, whose primary is in series with a high noninductive resistance. The electromotive force in the small resistance to which the moving coil is connected will decrease with increasing frequency, while at the same time the electromotive force induced in the secondary of the transformer will increase. The moving coil will be traversed by a current whose magnitude and phase depend upon the resultant of the two electromotive forces, and the coil will take up a position varying with the frequency, but not with the voltage. The instrument has a very open scale, 2.5 cycles either way from the frequency corresponding to the central point (43 cycles) of a particular meter sending the needle to the end of the scale.

COMPAGNIE ANONYME CONTINENTALE POUR LA FABRICATION DES COMPTEURS.

The works of the Compagnie Anonyme Continentale pour la Fabrication des Compteurs are located at 9 Rue Petrelle, Paris. The company was formed in 1853 and for years made gas meters and water meters. With the rise of the electrical industry, the manufacture of electric meters was taken up in 1885.

BUILDING AND EQUIPMENT.

The building is three stories high and is built with a central court, which is roofed with glass. The heavy machines used for operations on castings for water meters and for punching sheet metal for gas meters are located on the ground floor of this court. The lighter machine work and the assembling and testing of electric meters are done on the upper floors, which are lighted by the court. The machinery is group driven by 3-phase motors connected to the local supply mains.

There is little or no American equipment in the works. Turret lathes are used freely, on account of the large number of small parts required by electric and gas meters. Some of the machinery used for making gas-meter parts has been designed and built by the company; an instance of this is a machine for milling brass gear wheels. The blanks are assembled to a length of about 6 inches on a mandrel, which revolves under a rotating cutter, whose general form is that of a worm; the work is flooded with oil. While one set of blanks is being cut a second set is being strung on the mandrel and mounted ready to start under the cutter when the first set is finished.

No female or child labor is employed, the reason being that women and children are not insurable against accident.

DIRECT-CURRENT WATT-HOUR METERS.

The "Vulcan" direct-current meter has been made by the company since 1898. In general principle it is the same as the Thomson meter. The commutator is placed at the top of the spindle and projects above the main cover of the meter. A small cap fits over the bracket supporting the shaft and the brushes, and may be sealed independently of the case proper. Thus the lighting company may have access to the commutator for cleaning, maintaining its seals, while the municipal authorities in charge of meters may have their seal on the case as a whole.[1] A third seal at the bottom of the meter, also under the lighting company's control, gives access only to the terminals and to the screw that enables the weight of the rotating element to be taken off the jewel when the meter is to be moved.

The register is placed near the middle of the shaft, between the field coils and the damping device. The latter is not the familiar disk, but is a cylinder similar to the one used in the Fort Wayne type K induction meter. It differs from the latter in being greater in diameter, shorter in axial length, and in being made of copper. The cylinder is carried from the shaft by three light ribbed arms. The object of the construction is to avoid the dead material of the usual disk and to have all the metal passing through the air gap at one maximum linear velocity for a given number of revolutions per minute. The magnets are four in number and are placed as far as possible from the field coils. They are placed in such a position as to suffer the least change due to short-circuit currents in the field coils. The adjustment of full-load speed of the meter is made by screwing the copper cylinder up or down on the threaded spindle.

[1] This arrangement is said to be a legal requirement in Austria.

The spindle is pivoted in a spring-supported sapphire jewel. The company has tried artificial ruby jewels as substitutes for sapphire; but while they are very hard, they have the drawback of greater brittleness, so that, on the whole, they are not preferable to sapphire.

Constantan wire on porcelain spools is used for the extra resistance in the armature circuit. This gives a higher temperature coefficient than would be desirable in meters for locations subject to wide variations of temperature. As most meters are installed in dwellings, where the temperature does not vary widely, and as the legal requirements here are not very rigorous in this particular, the company prefers to use constantan, to save space and cost. For cases where meters of low temperature coefficient are required it uses resistance coils of high temperature coefficient.

The commutator is of silver, and each brush is made of a number of silver wires side by side. The normal full-load speed of the armature shaft is 60 revolutions per minute. The current in the armature is 22 milliamperes.

COSINUS INDUCTION WATT-HOUR METERS.

The company makes induction watt-hour meters under the trade name "Cosinus." These meters are similar to other induction meters, but have the distinguishing feature that no lag coil or loop is used to produce the adjustment for inductive loads. The rotating disk of an induction meter acts as a closed secondary for the potential flux and also for the main flux and gives a resultant potential flux and main flux, respectively. It is stated that the Cosinus meter has such an arrangement of the magnetic circuit that the reaction due to the disk gives the lag adjustment. A fine adjustment, however, is provided by a screw that varies the width of an air gap in a leakage path. The disks are of copper, the jewels are sapphire, and the clock register is supplied in preference to the cyclometer form. The full-load speed is 60 revolutions per minute.

DEPASSEMENT WATT-HOUR METERS.

The "depassement" meters of the Compagnie Continentale are made in two types. In one of these an induction meter of regular construction runs at a speed proportional to the power taken by the customer. A second motor element runs at a constant speed, and is operated by the line current only. The meter spindle and the spindle of the constant-speed element are geared differentially to the register, so that the latter will totalize the difference of the revolutions of the two spindles. Furthermore, a ratchet is provided, so that the register can not be moved backward. Hence the register will record only when the speed of the meter spindle exceeds the constant speed of the special motor element. The principle of the latter is of interest. If the voltage could be kept constant, an induction-meter element could be used, with a series coil of fine wire connected (with a suitable non-inductive resistance) across the mains. However, the speed of such a motor would vary as the square of the voltage. For this reason an induction-meter element is used, in which both current and potential cores are wound with coarse wire; the two windings are in parallel, and the whole in series with the line. By suitable means a dis-

placement of phase is produced, giving a driving torque. The counter torque is not supplied by a permanent magnet, but by a laminated electromagnet also in series with the line. Since both the driving torque and the counter torque vary as the square of the current, the speed will be constant, if friction be neglected, for all values of the current. In practice, since the torque falls off as the square of the current, this form of depassement meter can not be used below one-third of full load. That is, a meter of 300 kilowatts capacity would be used where the agreed maximum (above which the meter is to register) is not less than 100 kilowatts. The normal speed of the "constant-speed" element can be varied by sliding the laminated brake magnet in or out radially, to vary its retarding torque for a given current. Thus, if the customer's load increases, the limit above which he must pay an excess charge can be raised.

To avoid the difficulties which would attend the construction of this type of meter in various current ranges, but one range is made, namely, 10 amperes; for other ranges, current transformers are used.

The depassement meters are also made as two-rate meters with the same power limit for both rates, as two-rate meters with depassement for one of the rates and total registration for the other, and as two-rate meters with different depassements for the two.

As the preceding meters are expensive, their use is limited to the more important installations. To provide a less expensive depassement meter for smaller installations, the Cie. Continentale makes another type, applicable only to noninductive loads. It is the same in general principle as an ordinary induction meter, but has two windings on the laminated core which ordinarily carries only the series winding. One is a series winding connected in the line as usual, the other a fine wire coil connected across the line in series with a high noninductive resistance. The ampere turns of the fine coil oppose those of the coarse coil, and hence with the current in the latter below the value giving equal and opposing ampere turns, the meter would run backward if it were not for a ratchet which prevents backward motion.

COMPAGNIE DE CONSTRUCTION ELECTRIQUE.

The works of the Compagnie de Construction Electrique are located in Issy-les-Moulineaux, a suburb of Paris. The buildings are quite modern, having been erected in 1909. They are fireproof, one story high, and have the saw-tooth roof. The lighting is excellent, and ample room is provided for the work and for growth of the business.

EQUIPMENT—LABOR.

The machine tools are driven by line and counter shafting by a three-phase motor connected to the local supply mains, which also furnish current for meter testing. As a precaution against possible failure of supply, a gas engine is installed, direct-connected to an alternator which can supply current for operating the machinery and for the meter testing.

American machine tools are better represented in this factory than in any other French factory visited by the writer. Among the tools noticed were a Bliss press, Warner & Swazey turret lathe, a Prentice

three-spindle drill, and several other machines. When asked for his opinion of American machine tools, M. David, director of the company, at once spoke of the accuracy of their construction.

All work is done by men, no female labor being employed. The piecework system is largely used. The winding of potential coils of induction meters is accomplished at a very low cost, the company furnishing molded spools, wire, flexible terminal leads, and paper for covering the coil; each man then performs all the operations to produce the finished coil. The same idea is applied to the assembling; parts are served out in trays, each holding those needed for 10 meters. Each workman assembles his own lot of meters, and is responsible for their condition when they come into the testing room. If any faults are found in a meter it is sent back to the man who assembled it, who must make it good on his own time. The advantages claimed for this system are that it puts much greater responsibility on each man, and also develops him into a more skillful workman than he would be under the system of having each man perform but one operation.

B T INDUCTION WATT-HOUR METERS.

The company's product is limited to induction watt-hour meters and their accessory apparatus, such as current and potential transformers. The meters are known by the trade designation "B T"; they were formerly known as the Batault meters. The line includes single-phase, two and three wire meters; polyphase meters for balanced and for unbalanced loads; three-phase four-wire meters; prepayment, two-rate, and "depassement" meters. Standard current ranges include 2, 3, 5 . . . up to 300 amperes; the 3-ampere and 5-ampere ranges are most in demand.

While the general principle of the B T meter is that common to all induction meters, some points of design and construction are of interest. Copper disks are used, the company having given up the use of aluminum. Copper disks are preferred because their greater torque and greater inertia make the meter less sensitive to increase of friction, due to the collection of dust on the disk or in the gearing. The complete moving system with copper disk weighs 55 grams. The company states that the wear on pivot and jewel, when copper disks are used, is not much greater than that with aluminum disks weighing 20 grams; the torque with the copper disk is 80 to 100 millimeter-grams, as against 30 to 40 for usual meters having an aluminum disk. They state that the ratio of torque to weight, on which stress is laid by some designers, is of little consequence, since the friction of the pivot and jewel is absolutely negligible in comparison with that of the gearing. The company furnishes regularly the clock dial; cyclometer dials are not recommended by it, but will be furnished on special order.

The full-load adjustment is usually made (with the damping magnets fixed in the position for maximum drag) by screwing an iron bridge piece toward or from the laminated poles of the motor element, so as to vary the reluctance, and hence the driving torque. An adjustment of the drag magnets may be made if necessary. The light-load adjustment is made by a lateral micrometer adjustment

of the iron bridge piece, so as to give a slight dissymmetry to the magnetic circuit. The lag adjustment is made by the vertical movement of a copper stamping, which has two rectangular openings, so that it can be slipped on the stampings bearing the shunt and series coils. This rectangle is slipped over the poles after all the coils are in place. Rectangles of various thicknesses are kept in stock to provide for various types of meters. The rectangle may be readily removed and replaced without disturbing any other part of the meter.

The power loss in the potential coil and that in the series coil at full load are said to be less than 1 watt each. The meters up to 10 amperes will start on 1 per cent; above 10 amperes, on 0.5 per cent of rated power.

POLYPHASE, TWO-RATE, AND DEPASSEMENT METERS.

In the company's polyphase meter, two disks are used, each being acted on by a motor element and a drag magnet. The poles of the lower motor element point downward, and those of the upper element point upward, thus separating the working magnetic fields as far as possible to avoid interaction between the elements. It is claimed that this construction has been found so good that tests on polyphase and on single-phase current show no difference, thus permitting the use of the simple single-phase test with one wattmeter.

The company's two-rate meter has a motor element (or elements) as in the regular meters, but has two registers. One or the other of these registers is connected to the spindle by a clock mechanism in a separate case. The meter and the clock are connected by three wires. This construction is preferred by the company to that in which clock mechanism and meter mechanism are contained in the same case.

The "depassement" meter made by the company is identical in construction with the regular meter, but has in addition a cylinder of nickel carried on the shaft and revolving in the field of a permanent magnet. The meter will not start until a certain specified load is exceeded, when it will run and register the excess above the specified load. The adjustment of the specified load is accomplished roughly by sliding the nickel cylinder on the shaft, so as to vary the amount of nickel in the field; finer adjustment is then made by means of a micrometer screw forming part of a magnetic shunt to the permanent magnet.

The standard instruments used in the company's testing room are Siemens & Halske & Cie. des Compteurs wattmeters. Test is made on actual load, using incandescent lamps.

The company obtains most of its supplies from French, Italian, and Spanish sources, and sells its product principally in France. It does not supply any meters to the United States.

COMPAGNIE FAC.

The Compagnie FAC, whose works are located at 81 Rue St. Maur, Paris, makes a large variety of switchboard and portable voltmeters, ammeters, and wattmeters. A conspicuous feature of the product is the low-priced small instrument, for the manufacture of which the company is specially well equipped.

EQUIPMENT AND METHODS.

The work is carried on in a building three stories high. A feature that attracts attention is the fact that each machine is driven by a small direct-current motor, usually attached to the ceiling. This reduces to a minimum the belting and shafting required, and thus gives better lighting and less dirt than the more usual arrangements. In circuit with each motor is a small ammeter, located so as to be conveniently seen by the operator, who can thus tell at a glance whether the motor is carrying the usual load; in case of undue friction or other difficulty, the trouble is known before it results seriously.[1] The company has striven to reduce the cost of its instruments, not by the use of inferior material, but by designs that eliminate as much as possible the work of assembly, even at the cost of very special fixtures and machines. This policy is possible in the manufacture of small indicating instruments, which are made by the thousands.

The machines in use are mostly of French manufacture, a few only, including a three-spindle drill, being of American make. A small milling machine with three adjustable heads is used in milling the cases of "watchcase" pocket instruments. Much of the equipment suggests watch manufacture, on account of the small size of the springs, pivots, and other parts. The equipment, which is very complete, includes a plating department. The lighting of the works is very good, and the general arrangement is convenient.

The company classes as "precision" apparatus only the permanent-magnet moving-coil type; it believes that moving-iron instruments can not be included under this head, and furnishes them as "industrial" instruments, which may, however, be had with "precision mounting," which includes the use of sapphire or ruby jewels.

PRODUCTS—AIR-DAMPING.

All instruments are of round pattern, with the exception of the twin ammeter-voltmeter for automobile use. Six diameters of scales are used, ranging from 60 to 250 millimeters (2.4 to 9.8 inches), and a large variety of cases are supplied. Damping may be applied to all moving-iron instruments except the smallest. Instruments having scales 80 millimeters (3.1 inches) in diameter have a damping vane attached to the index, moving in a sector-shaped damping compartment, of which the scale plate forms the back and the cover glass the front. The vane is thus visible, and, in fact, the outer end of the vane serves as the pointer. For larger instruments a different arrangement is used. Two square pistons, attached by light stamped arms to the moving system, move in two annular chambers in a circular metal box, which is concentric with the moving system. As the latter moves, one piston compresses the air in its chamber, while the other one rarefies it; this arrangement is said to give uniform damping for all parts of the travel of the moving system. This damping arrangement is also applied to the largest permanent-magnet moving-coil instrument, in which the high moment of inertia of the long index makes it difficult to get sufficient damping by Foucault currents in the coil frame.

[1] In the writer's opinion, there is a large field for the use of small, cheap, well-made instruments in connection with motor drive. This field could be developed by educating the motor users.

WATTMETERS—FLUSH INSTRUMENTS.

The company makes wattmeters on the electrodynamometer principle in four sizes; the smallest has a scale of 80 millimeters (3.1 inches) in diameter. This is the smallest wattmeter the writer has seen. It has the air-damping arrangement above described for 80-millimeter instruments, and is not made for currents above 15 amperes. The price is moderate—$7.95.

Four sizes of instrument are made in flush pattern; the smaller sizes make a very neat appearance on small switch panels for accumulator charging, electromedical purposes, etc. The smaller flush pattern instruments are also mounted, singly or in pairs, on finished wooden bases. These bases may have covers hinged to them to protect the instruments, or a carrying box may be supplied for the same purpose. Both arrangements are neat and attractive, and the prices are moderate; they should have a large sale to amateurs and others who need to make measurements of moderate accuracy. The company also supplies its precision direct-current instruments in similar mountings, for more accurate work.

LAMP-TESTING AND AUTOMOBILE INSTRUMENTS.

Combined volt and ampere meters are made in a large number of styles, chiefly for use in battery testing. For testing incandescent lamps three types of instruments are supplied, namely, ammeter only, ammeter and voltmeter (separate movements) in one case, and wattmeter.

For automobile use, the company makes small flush-pattern ammeters and voltmeters with square flush plates of finished brass. These plates are similar in style and size to the plates used in the United States with flush switches. Single instruments are furnished in this style, also wider plates containing ammeter and voltmeter side by side.

Other products of the company include battery charging panels, polarity indicators, insulation testers, pyrometric apparatus, and a magnetoscope. The last is a simple device for measuring the relative strengths of magnets of a given form. It is easily and quickly operated, and is low in price—$2.32.

The company has in course of development a line of hot-wire instruments; also a line of registering instruments, and at present constructs some of these on special order.

COMPAGNIE POUR LA FABRICATION DES COMPTEURS ET MATÉRIEL D'USINES À GAZ.

The electrical works of the Compagnie pour la Fabrication des Compteurs et Matériel d'Usines à Gaz are located at 16 and 18 Boulevard de Vaugirard, Paris. The company made gas and water meters years before the electrical industry was in existence; it has made electric meters from the beginning of the use of such meters. It is now making about 400 electric and 200 water meters per day, in addition to gas meters. The latter are made in two other factories in another part of the city.

EQUIPMENT—LABOR.

The works are extensive and provide for practically all the operations required in meter manufacture. A foundry on the ground floor produces brass and aluminum castings; iron castings for electric and water meters are purchased from outside foundries. Much of the machinery is special, and little is of American manufacture. One American machine noticed was a heavy turret lathe for finishing the interior of brass water meters, which require very accurate workmanship. In the coil-winding department are a number of special machines, one of which winds six coils at once. For doing "universal" winding two types of machine are in use. The more recent one is said to do the work as well and as rapidly as the other, and the cost was only a fraction of that of the other.

There is an absence of the female labor so common in American meter and instrument factories. Men do the winding of coils, for which female labor is usually considered to be well adapted. The local regulations do not allow women and children to work as many hours a day as the men, and employers can insure only men against accidents.

ASTATIC DIRECT-CURRENT WATT-HOUR METERS.

The electric product of the company includes both integrating and indicating apparatus. Their model B watt-hour meter[1] is constructed on the general principle of the Thomson "recording wattmeter," but has a flat disk armature composed of three form-wound coils incased in insulating material. This type of armature has the great advantage of being astatic to uniform stray fields. The drag magnets are at the top of the spindle, the armature and commutator at the bottom. The register is placed in the middle and has six dials, the upper four being the ones usually read and recorded, and having black figures on a white ground. The two lower dials have white figures on a black ground and red pointers; the lowest dial has 100 divisions. These lower dials are for greater convenience in testing the meter as a whole, including the gearing ratio. The drag magnets are held in a fixed position and an iron bridge piece near the poles has two iron screws which can be adjusted so as to vary the flux shunted from the magnet, and hence the flux through the drag disk, which is made of aluminum. The brushes can be turned slightly on the holder, withdrawn, and afterwards replaced in the same position with the original tension; the latter can be adjusted by a set screw. The meter is said to start at 0.5 per cent of rated load and to have a maximum error of 3 per cent at 5 per cent of rated load.

Model B meters are also made for switchboard service, up to 2,000 amperes two-wire or 1,000 amperes three-wire, with the entire current passing through the series coil; above these values a shunted meter is used. In the latter the current through the meter (with rated load in the line) is 50 amperes, and the drop at the shunt terminals is 300 millivolts.

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[1] Within the last few years meter makers in the United States have been urged to use the expression "watthour meter" in place of the much used but incorrect terms "recording wattmeter" and "integrating wattmeter," and the term "watthour meter" is coming into use. Some objection has been raised to the use of "watthour" as one word by those who prefer the form "watt-hour." It is therefore interesting to note that the French company here referred to goes so far as to use "wattheuremetre" as a single word.

FIVE-WIRE DIRECT-CURRENT WATT-HOUR METERS.

In addition to the two-wire and three-wire arrangements well known in the United States, model B meters are also made for five-wire circuits. The five-wire system is used to some extent abroad, to save copper; it has never been favorably considered in America. It has three "neutral" wires, which carry only the unbalanced currents, and hence need not be so large as the two "outers." In the model B five-wire meter there are two field coils above the armature, one in each outer, of wire or strap heavy enough to carry the rated current in the outer. Below the armature are two field coils of half the number of turns of the others, inserted in the two neutrals next to the outers. The third central neutral is attached to a binding post of the meter (but has no series coil) in capacities up to 75 amperes; from 100 amperes up, the central neutral wire does not enter the meter.

The company's type A, an older form, is similar to the classical Thomson meter, but has the commutator at the bottom of the shaft and the register at the top, with the drag disk immediately below. It is stated that the construction is such that the meter can be used equally well on direct current or on alternating, including inductive loads.

INDUCTION WATT-HOUR METERS.

The company's induction watt-hour meter, model A. C. T. III, is made with one motor element for single-phase two-wire and three-wire or three-phase balanced circuits; with two motor elements acting on one disk for unbalanced three-phase three-wire or two-phase three-wire or four-wire circuits; and with three motor elements for three-phase four-wire circuits. For this latter use they do not consider the meter with two motor elements accurate enough, since this meter is accurate only when the three voltages are equal and their phase relation to each other is symmetrical. Their three-element meter has a longer shaft than the other forms, with one disk at the bottom acted on by two motor elements, and another disk at the top acted on by the third motor element and the drag magnet. Their meter for two-phase five-wire circuits has two motor elements wound as for single-phase three-wire circuits, acting on one disk.

The shunt-coil loss of A. C. T. III meters is given as 0.9 watt per element and the starting load as 0.5 per cent of the rated load. The lag adjustment is made by a copper **U**-shaped strap which surrounds the potential core; the ends of the **U** are joined by a screw whose length is about twice the distance across the top of the **U**, and which is of copper for half of its length and resistance alloy for the other half. By turning this screw, the resistance of the loop circuit can be continuously varied until the desired lag adjustment is secured, when the screw contacts may be made secure by tightening locknuts on the screw against the copper loop. The armature is of aluminum, and the torque is about 25 millimeter-grams for one motor element, or 45 for two elements. The aluminum disk is used with the clock form of register, which the company prefers to supply.[1] On special order they supply induction meters with cyclometer dials, but in this case they prefer to use copper disks, partly to increase the torque to over-

[1] This does not apply to tramcar meters, for which cyclometer dials are standard.

come the extra friction and also to increase the moment of inertia, to enable the rotating element to overcome extra friction occurring momentarily, such as might occur at the moment when several wheels of the dial were to be turned at once.

AMPERE-HOUR METERS.

The "O'K" ampere-hour meter, made by the Compagnie des Compteurs, has been extensively used, as about 300,000 have been manufactured. It is a motor meter, with a strong permanent magnet between whose poles rotates a drum armature without iron, having form-wound coils, which is in parallel with a manganin shunt connected in one of the line wires. The commutator segments and the brushes are of gold, and the diameter of the commutator is small, namely, 3 millimeters (0.12 inch). There is no damping device; the armature being connected to the terminals of a shunt in one of the lines, runs at a speed practically proportional to the drop on the shunt. In the smaller sizes, the rate of the meter (at full load) is adjusted by varying the resistance of the shunt. In larger sizes, where this would be inconvenient, a magnetic shunt is varied.

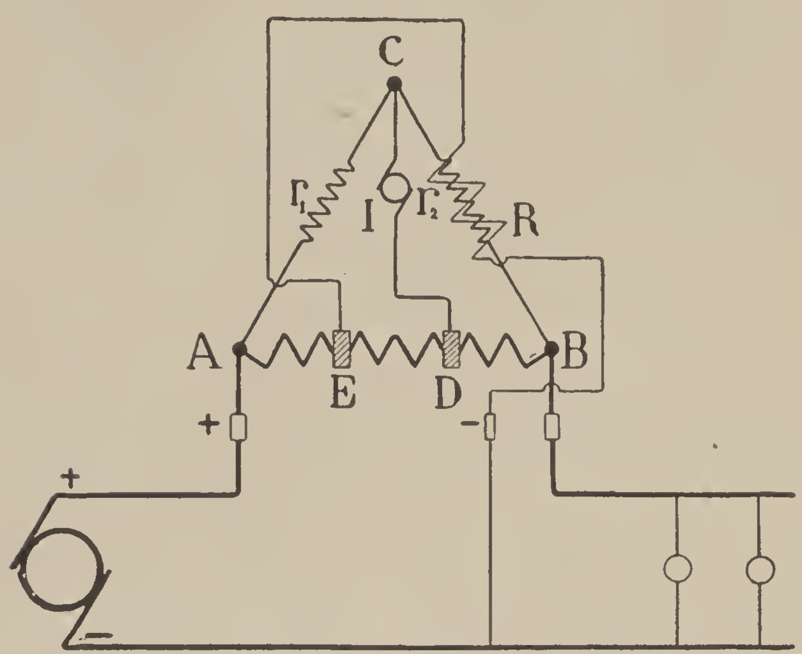

FIG. 2.—Diagram of circuits, O'K watt-hour meter.

Below 15 amperes the O'K meters are not compounded; for 15 amperes and above, a current of about 0.01 ampere is taken from the line to provide an initial starting torque. The three-wire O'K meter has two armatures which are magnetically in series between the poles of the magnet. The revolutions of the two armatures are totalized on one register.

WATT-HOUR METER WITH SHUNTELET.

The preceding O'K meters are marked to read in hectowatt-hours or kilowatt-hours, on the assumption that a certain nominal voltage is maintained at the consumer's premises. An interesting variation is the O'K watt-hour meter with "shuntelet," which is an O'K ampere-hour meter provided with an additional device which causes the registration to be proportional to the watt-hours, for voltages within 10 per cent of the normal. The operation of this meter may be seen from figure 2. A shunt AB is in series with one line wire, and the two resistances r_1 r_2, which have a high temperature coefficient, are connected in series with each other and across the shunt. The armature I is connected between the junction C and the adjustable point D. Around the resistance r_2 is wound a fine-wire heating coil R, which is connected across the mains. As the voltage varies, the resistance r_2 varies, and by shifting the contact D, the speed of the armature may be made to vary as the watts, within the stated limits ($\pm$10 per cent). A thermocouple heated by the heating coil supplies a current which

overcomes the friction torque at light load. The remaining adjustment, namely, the full-load speed, is made by a magnetic shunt. The power taken by the heating coil is said to be from 3 to 4 watts.

SPECIAL AMPERE-HOUR METERS.

Another variation of the simple O'K ampere-hour meter has a variable magnetic shunt, which is graduated in terms of voltage, the range being from 10 per cent below to 10 per cent above a normal value. This meter may thus be adjusted at the point of use to read watt-hours, for any voltage within the above limits.

The O'K ampere-hour meter is also made for battery charging. In this form, a special register may be supplied, having a dial of large diameter. One revolution of the index of this dial corresponds to a

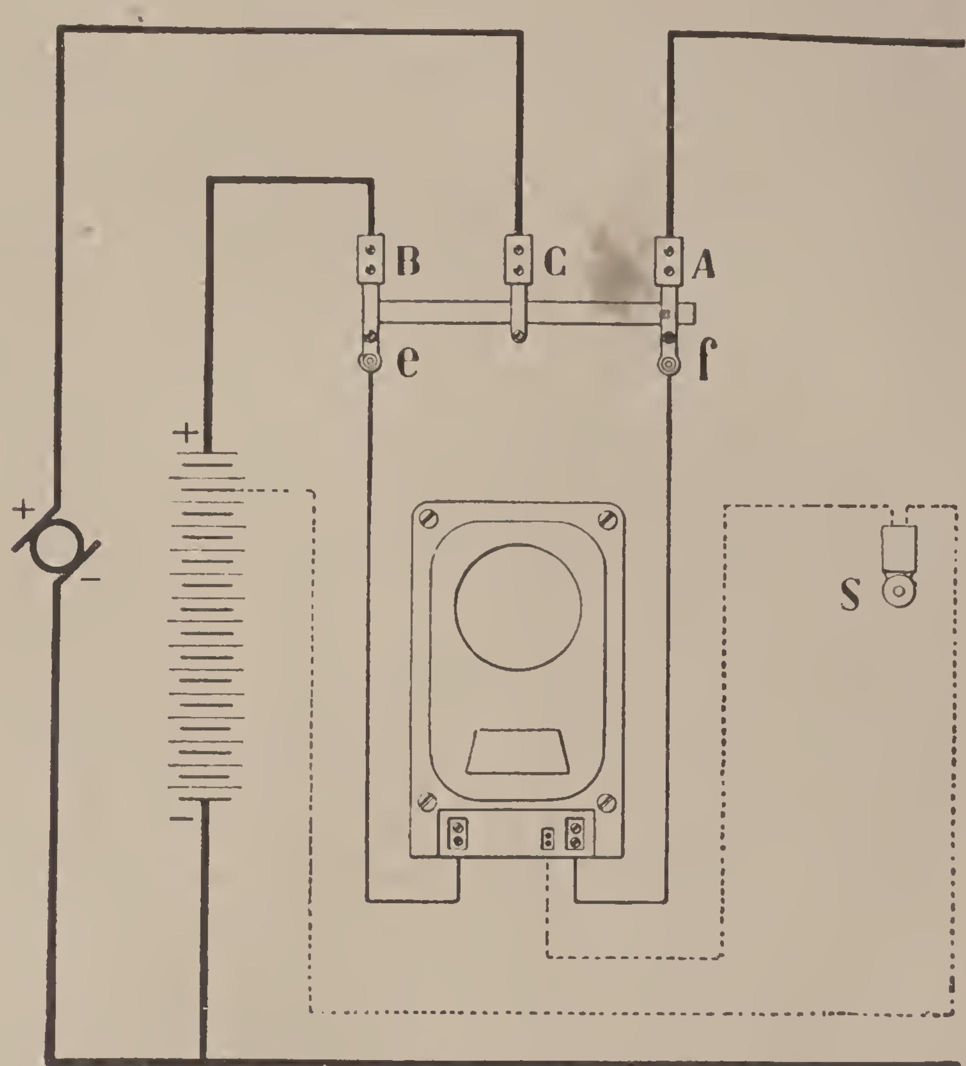

FIG. 3.—Diagram of connections, O'K ampere-hour meter for storage-battery use, with "efficiency" shunt.

quantity somewhat greater than the maximum charge. This dial shows the state of the battery; three additional dials of the usual diameter are provided to totalize the successive discharges. Another arrangement is shown in figure 3. The meter is connected across the ends of a shunt BA having a central connection C which is adjustable. The point C should be shown nearer to A, for the practical case, since the ratio BC÷BA should be adjusted to equal the ampere-hour efficiency of the battery. When the battery is being charged, the drop of potential at the meter terminals *ef* (for a given current) is proportional to BC; on discharge, the drop for the same current is proportional to BA. Hence the meter will run faster on the same current when discharging, and its reading at any time shows the charge remaining in the battery. Contacts may be provided, so

that the bell S will be rung at the end of charge or discharge. Other special arrangements of O'K meters are made to meet special requirements in battery work. For electrolytic work, the O'K meter is provided with two dials—one of the usual form, to totalize the amount of metal deposited, and a dial of larger diameter which can be used to determine the amount of metal for each operation. Both dials are graduated in grams or multiples of grams.

DEPASSEMENT, TWO-RATE, AND VARIABLE-RATE METERS.

The "depassement" meter of the Cie. des Compteurs is of the type in which a meter of regular form (A. C. T., B, or O'K) is provided with a cylinder of nickel carried by the spindle and revolving between the poles of an auxiliary permanent magnet. The torque due to hysteresis in the nickel will be constant for all speeds (neglecting eddy currents), and hence the meter will turn only when the load exceeds a given maximum, and its speed of revolution at any moment will correspond to the excess power.

The two-rate meters of the Cie. des Compteurs contain a regular meter of suitable type and a clock mechanism, both in one case. The clock mechanism is supplied either for hand or electric winding. Multi-rate meters are also made which allow four rates of charge in the 24 hours.

The company also supplies meters with the Mahl variable-rate system. The object of this system is to vary the rate throughout the 24 hours of the day, charging the lowest price when the station load is lowest, and vice versa. These meters have two dials; one showing the total ampere-hours or hectowatt-hours used, and the other the total in monetary units (francs). The variation of the rate is accomplished by a special mechanism interposed between the rotating spindle and the monetary dial. This mechanism contains a cam, whose profile is shaped as desired, in accordance with the load curve of the particular station. A pointer attached to the mechanism moves over a scale and shows the rate in force at any moment.

TRAMWAY AMPERE-HOUR METER.

Other special meters are made, including prepayment and tramway forms. The latter is the O'K ampere-hour type, with the meter element suspended by a spring inside an iron case. For this meter the company supplies the simple cyclometer dial, which is preferred because it can be read by unskilled men; the motorman should be able to check his own use of current. Further, there is no light-load problem with tramcar meters, so the extra friction of the cyclometer dial is not a serious matter. The saving of current due to the use of tramcar meters was estimated by M. Delalandre, of the Cie. des Compteurs, as about 12 per cent. This estimate is said to be borne out by the experience of several Paris electric railways.

FRICTION NEUTRALIZER FOR WATT-HOUR METERS.

In order to minimize the effect of friction on light-load accuracy, especially in commutator meters, the company applies (on special order) a device called a "demarreur." This is a small motor which

runs constantly, being connected across the line. The motor is geared to a shaft carrying an eccentric, which is connected to the brush-holder yoke. The brushes are thus rocked back and forth through a small angle, the peripheral speed at the commutator surface being greater than the maximum peripheral speed the commutator would have with respect to a stationary brush. The starting friction is thus eliminated, and it is said that a meter so equipped will start at 0.2 per cent of full load and will be accurate at 0.5 per cent load. The use of the demarreur is limited to large and important meters, such as the totalizing meters of central stations, which run at very low loads for some parts of the 24 hours. The power required by the demarreur is small—about 2.5 watts per 100 volts.

DIRECT-CURRENT AMMETERS AND VOLTMETERS.

The direct-current ammeters and voltmeters of the Cie. des Compteurs ("System Meylan d'Arsonval") have a coil wound on a copper or aluminum damping frame which is eccentrically pivoted, so that one side of the coil passes through the single air gap in the magnetic circuit. The construction is such that the coil can be put in place or removed without disturbing the magnetic circuit. The air gap is about 2 millimeters (0.08 inch), and the field strength is given as 1,200 to 1,400 gausses. The sapphire jewels are spring supported. The cases are sector shaped to give the least area occupied for a given length of scale. Six models are made, with scale lengths ranging from 60 to 330 millimeters (2.4 to 13 inches). The design is such that the motion of the index is slightly underdamped; the company considers this better than critical damping, which gives room for the suspicion that friction is present. Voltmeters take less than 0.02 ampere, and the scales are so divided that each division represents 1, 2, 5, or 10 volts. Ammeters have interchangeable shunts, with the standard drop of 100 millivolts. The shunts are designed to give not over 150° C. rise of temperature at full load, though it is said that they will stand 300° C. without injury. In the case of large shunts, where it is necessary to keep down the power lost in the shunt, and where the temperature coefficient of the instrument is not important, the shunts are made for 60 millivolts drop.

When direct-current voltmeters are desired with large divisions in the vicinity of the working point the company can meet the requirement in two ways. In the first, a special shape is given to the magnet poles; this increases the length of a division near the working point to two or three times the length of a division on a uniform scale of the same length, and gives the advantage that the zero is on the scale; hence, changes of zero reading from any cause can be detected. The other plan is the "suppressed-zero" method, in which an initial tension is given to the springs. This increases the division length to four or five times the normal, but has the disadvantage that the zero reading is off the scale.

MOVING-IRON INSTRUMENTS.

Moving-iron switchboard instruments are made in four sizes. They are supplied for direct current when a low-priced instrument is required. For this use the calibration is made with direct current,

and the + terminal is marked in order that the polarity may be made the same in use as in calibration. The voltmeters require 2.5 to 5 watts per 100 volts. All sizes have air damping. Ammeters are made self-contained up to 1,500 amperes; for ranges from, say, 800 to 1,500 amperes the company asks the customer to indicate the manner in which the conductors will be run to the instrument so that the factory calibration may be made under the same conditions of stray field. For large currents, or for use on high-voltage circuits, ammeters are also supplied with current transformers. The secondary current is 2 amperes for transformers of only approximate ratio, the transformer and ammeter being calibrated together as a unit, or 10 amperes, for transformers adjusted to a definite value of ratio.

HOT-WIRE AND ELECTRODYNAMOMETER INSTRUMENTS.

Hot-wire instruments are made in two sizes, in cases uniform with the preceding. The hot wire in the voltmeter is surrounded by a closely wound spiral of fine enamel-insulated wire in series with the working wire, which latter is thus thermally shielded, reducing the radiation from it, and therefore reducing the power spent in the instrument.

Electrodynamometer wattmeters are made in three sizes, uniform in style with the preceding. To keep the drilling plan the same as for other instruments of the same size, the current-terminal studs are bored out and the potential studs are passed through them. Induction wattmeters are made in horizontal edgewise form, with glass case. To overcome the large temperature coefficient of this type of wattmeter, the magnetic circuit contains small bridge pieces of Guillaume nickel-steel alloy, of which the permeability varies with the temperature.

FRAGER LAGGING DEVICE—SHUNTED WATTMETER.

The company makes accessory apparatus for the foregoing, including current and potential transformers. Synchronism indicators, phase meters, and registering instruments are also made, the last named in a large number of types. Space permits the mention of only a few points in regard to them. Registering wattmeters on the electrodynamometer principle are "lagged" to be correct on alternating current by the device of M. Frager. This consists of a short-circuited coil placed within the series coil. The combination of the flux due to the main current and that in the closed lag coil gives a resultant flux, which lags behind the main current. By proper choice (or adjustment) of the lag coil this angle of lag may be made equal to the angle of lag in the potential circuit. The principle is similar to that of the lag coil in induction watt-hour meters. The shunted registering wattmeter was devised by M. E. Grassot. In general structure it resembles a permanent-magnet moving-coil instrument. The field magnet is of special soft steel of low hysteresis and is wound with fine wire, which is connected, with added resistance of low temperature coefficient, across the mains. The moving coil is of coarser wire and is connected, with some added resistance, to the

terminals of a shunt, which may also be used to operate other instruments. The moving-coil circuit is said to be almost completely compensated for temperature; it takes less than 1 ampere at full load, the drop at the shunt terminals being then 300 millivolts, the same as for the company's shunts for hot-wire ammeters. The shunted wattmeter may be used on a three-wire installation; in this case a double shunt may be used having three brass blocks and two sets of alloy strips. The positive generators have their neutral terminals joined to one end of the double shunt, the negative generators similarly to the other end, and the neutral line wire starts from the center block of the double shunt.

PORTABLE INSTRUMENTS—THE ONDOGRAPH.

Portable voltmeters, ammeters, and wattmeters are made on the same general plan as the switchboard instruments previously described. Portable direct-current millivoltmeters are regularly of 2 ohms resistance and give full deflection for 100 millivolts. The temperature coefficient is 0.1 per cent per degree Centigrade. This may be compensated, if so ordered, by the use of a nickel-steel magnetic shunt to the permanent magnet. This latter construction is regularly used in the precision portable millivoltmeters made by the company. The precision electrodynamometer voltmeter is supplied in an astatic type, when required. This makes the instrument independent of (uniform) stray fields and obviates the necessity for taking the mean of two readings with opposite directions of the current when checking or using the voltmeter on direct current.

The Hospitalier ondograph is an instrument for tracing alternating-current wave forms. A small synchronous motor is geared to a rotating commutator and also to a drum bearing a paper chart. The gearing ratios are such that while the motor makes 1,000 revolutions, the commutator makes 999, and the drum one-third of a revolution. A permanent-magnet moving-coil galvanometer, specially designed for high torque and aperiodic motion, moves a pen over the paper chart, the motion of the pen, at the middle point of its travel, being at right angles to the motion of the paper. The commutator is arranged to connect a condenser momentarily to the line whose voltage is to be traced; at this moment the galvanometer circuit is open. During the rest of the revolution of the commutator the condenser discharges through the galvanometer. The effect is practically to cause the galvanometer to follow the variations of the wave form at 0.001 of the actual frequency; thus on a 60-cycle circuit, a complete period is traced in 16.25 seconds.

THE GRASSOT FLUXMETER.

The Grassot fluxmeter may be termed an industrial ballistic galvanometer. It is made in a form similar to the company's direct-current voltmeters, but has the moving coil suspended on a silk fiber, connection being made by means of very fine silver strips, to give the smallest possible torsion. The throw of the coil is read by an index and scale, and may also be observed by optical methods, as a mirror

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is carried by the coil. In connection with small search coils whose number of turns and area are known, it may be used for magnetic measurements. Other applications of the instrument will suggest themselves to those who are familiar with ballistic methods.

Pyrometric apparatus forms an important part of the company's product, including thermocouple pyrometers and various types of Féry radiation pyrometers, the latter being made for temperatures up to 3,500° C.

MAISON GRAINDORGE.

The firm of Graindorge, located at 4 Rue de Borrego, Paris, manufactures moving-coil and moving-iron ammeters and voltmeters in a large number of sizes. Special attention is paid to the construction of small low-priced moving-iron instruments, of which the firm sells a very large number. In these instruments the scale plate forms one head of the spool on which the actuating coil is wound. A brass tube carries the fixed piece of iron and contains the bearings for the shaft on which the moving iron and the pointer are carried. These brass tubes with shaft, etc., are made in quantity, all alike for all ranges of ammeters and voltmeters, and they and the wound bobbins are carried in stock. As instruments are required to fill orders, the proper capacity bobbins are selected and into each is inserted a brass tube carrying the iron system. The tube is held in position by cement. In spite of the low price of these instruments, a scale is made by hand for each one. As a further illustration of the care used, the silk-covered wire used for voltmeters is dried and paraffined before use.

The low price at which these instruments are sold requires economical design as well as manufacture in quantity, with every possible effort to reduce cost. One way in which costs are reduced is by allowing a considerable amount of routine work, such as coil winding, to be done at the homes of the workmen.

Regular workmen employed in this factory earn 10 to 12 francs ($1.93 to $2.32) per day of 10 hours, while apprentices earn 7 to 8 francs ($1.35 to $1.54) per day.

The small ammeters and voltmeters above referred to are also made as incandescent lamp testers, either with ammeter alone or ammeter and voltmeter combined in one case.

JULES RICHARD.

The works of Jules Richard are located at 25 Rue Melingue, Paris. The product includes a great variety of registering instruments for meteorological and other scientific purposes. Over 800 varieties of registering instruments are made, of which over 40,000 have been sold. Specially graduated and figured paper is carried in stock for all the 800 varieties.

The buildings are of brick, of modern design, well arranged, and with good lighting. A 50-horsepower steam engine is direct-connected to a generator for the power circuit, and is also belted to a countershaft in the room above, where are located special dynamos for testing purposes. No American machinery is used, the reason given being that they do practically no automatic work, all their apparatus being accurately made by hand.

MOVING-COIL INSTRUMENTS—DOUBLE-SENSIBILITY AMMETER.

Permanent-magnet moving-coil instruments have a small iron rider that bridges across the pole pieces and thus diverts some of the flux from the moving coil. It is claimed that this increases the permanency of the magnet, and further, that by moving this rider to the proper position on the poles, as found by trial, the distribution of the useful flux can be modified so as to correct the scale for any small errors.

An interesting modification of the usual moving-coil ammeter for direct current is the "ammeter with automatic double sensibility." In this ammeter the moving coil is controlled by the usual two spiral springs over, say, the lower two-thirds of the scale. When the coil moves farther, a third spring also opposes the motion, and thus the current required for a given increment of angular deflection is increased. For example, the lower two-thirds of the scale may be graduated from 0 to 100 amperes, while the upper third extends from 100 to 300 amperes. This type of ammeter is intended for observing the running current of motors on the lower two-thirds of the scale and the heavy momentary starting currents on the upper third. It may also be used for observing the behavior of constant-potential arc lamps, which take currents much heavier than normal at starting, or when the carbons happen to come together. If an ammeter of the usual construction is used for these purposes, the angular deflection given by the normal current is too small for accurate reading.

The Richard registering electrical instruments include a hot-wire voltmeter, moving-coil and moving-iron ammeters and voltmeters, and dynamometer wattmeters.

GERMANY.

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT.

The Allgemeine Elektricitäts-Gesellschaft of Berlin is a large manufacturer of electrical apparatus and machinery. The present description is limited to electric meters, of which the company makes a large number.

DIRECT-CURRENT METERS.

Direct-current watt-hour meters are made in two general types, of which the first is a rotating meter on the Thomson principle. The lower bearing is of sapphire; the end of the shaft is hollowed out and rests on a polished steel ball. The bearing is filled with oil. This bearing is used in all A. E. G. meters. The following figures are given by the maker for the above type: Direct-current motor meters, up to 100 amperes—full-load torque, 65 millimeter-grams; weight of moving element, 125 grams; potential-coil loss (for 100 volts), 1.5 watts; series-coil loss at full load, 10 to 14 watts; full-load speed, 80 r. p. m. Direct-current motor meters, 150 to 1,000 amperes—full-load torque, 120 millimeter-grams; weight of moving element, 140 grams; potential-coil loss (for 100 volts), 1.5 watts; series-coil loss at full load, 15 to 30 watts; full-load speed, 60 to 80 r. p. m.

The second general type of watt-hour meter is the oscillating meter, which has not been used in the United States. The general construction of this meter is very similar to that of the first type above mentioned, except as to the moving element. This consists of a single rectangular coil of fine wire carried by a shaft, which also carries an aluminum damping disk. No commutator is used; current is led into and out of the coil by two fine silver spirals in the axis of rotation. The motion of the coil is limited by two stops carrying electrical contacts. When a contact arm on the shaft of the moving element touches one of the stop contacts, the circuit of a relay is closed, and the relay operates a switch, reversing the current through the moving coil and causing it to move toward the other fixed stop, when the current is again reversed, and so on. Each time that the relay operates it advances a ratchet wheel on the register one tooth. Thus the work of driving the register is performed by the relay, instead of by the moving element as in most meters. The friction of the usual commutator is also absent in the oscillating meter, the only source of friction being the bearings. To make the operation of the contacts more reliable, the circuits are so arranged that when contact is about to be made the voltage between the contact points is high, about 80 volts, thus assuring the closing of the circuit. The reversal of the circuit by the relay alters the connections in such a way that the voltage across the contact points at break is only two or three volts. The use of the ball bearing as previously described enables the meter to be

shipped or carried about without raising the moving system off the jewel bearing. The adjustment of the rate of the meter is made by varying the position of the stops, and thus changing the amplitude of the oscillations. The following figures are given for this type by the maker: Direct-current oscillating meters, 3 to 100 amperes—weight of moving element, 60 grams; potential-coil loss (for 100 volts), 1.4 watts; series-coil loss at full load, 5 to 10 watts; swings per minute, 60. Direct-current oscillating meters, astatic type, 150 to 10,000 amperes—weight of moving element, 75 to 151 grams; potential-coil loss (for 100 volts), 1.4 watts; series-coil loss at full load, 18 to 140 watts; swings per minute, 60. The potential-coil losses include the loss in the relay circuit.

In sizes up to and including 30 amperes, the list prices of oscillating meters are very slightly higher than those of the corresponding sizes of rotating meters; for 50 amperes and above, the prices of oscillating meters are appreciably higher, the 200-ampere oscillating meter listing about a third more than the same size rotating meter. The relay arrangement of the oscillating meter makes it possible to operate extra registers at a distance, which is often convenient for switchboard meters.

AMPERE-HOUR METERS.

The A. E. G. ampere-hour meter has a strong permanent magnet, between whose poles rotates an inverted copper cup with three fine-wire coils covering its outer surface. Inside the cup, but not touching it, is supported an iron core. The commutator is of silver, and has three segments. The armature circuit is connected to the terminals of a shunt. The full-load torque is given as 150 millimeter-grams, with a drop of potential in the shunt of one volt. A three-wire ampere-hour meter is made by placing two sets of armature windings on the copper cup, the two being well insulated from each other by micanite, and connected to two commutators, one at each end of the shaft.

A modified form of ampere-hour meter differs from the preceding in having spirally twisted commutator segments and an arrangement for moving the brushes up the commutator as the load increases. A coil is attached to the brush holder, and is connected in series with the armature. This coil is arranged to move over a projecting piece of iron attached to one of the pole pieces of the magnet as the current in it increases. The movement of the brushes up and down the commutator is said to assist materially in keeping the commutator clean, and the spiral twist of the commutator is arranged so that the torque per ampere is greater at light loads, thus tending to overcome the light-load friction. These meters are said to be correct within 2.5 per cent from $\frac{1}{20}$ to full load. The type without the above special feature is said to have the same error limit between $\frac{1}{10}$ and full load.

INDUCTION WATT-HOUR METERS.

The A. E. G. induction watt-hour meter does not differ appreciably in general construction from those made in the United States. The magnetic system consists of an Ш-shaped core, of which the

two outer projections carry potential coils, and the inner the series winding. The magnetic circuit is partially closed by a laminated iron bridge piece near the top of the three poles, and the aluminum disk revolves above the poles. A copper ring may be moved so as to give the lag adjustment. These meters are made for single-phase and for balanced three-phase circuits with one motor element and one disk; for these types the weight of the moving element is 32 grams, and the full-load torque is 60, 70, or 80 millimeter-grams, for 110, 220, and 440-volt meters, respectively; the corresponding losses in the potential circuit are 1, 1.4, and 2.4 watts, respectively. The full-load loss in the series coil is from 2 to 5.7 watts for current ranges of 5 to 100 amperes. The polyphase meter for unbalanced loads has two motor elements and two disks; the weight of the moving system is 75 grams, the torque is 120, 130, and 140 millimeter-grams, for 110, 220, and 440-volt meters; potential-coil and series-coil losses per system are the same as given above for single-phase meters. Three-phase four-wire meters have two motor elements, each having two series windings. If the neutral conductor is grounded, conductor No. 1 is taken through one series winding on one motor element; conductor No. 2 similarly through one series winding on the other motor element, while conductor No. 3 is taken through the remaining two series windings in succession. If the neutral winding is insulated, at least back of the meter, each of the four conductors is taken through a series winding.

ELECTRIC METERS RECORDING TIME ONLY.

The "time meter" for electric circuits as used to some extent abroad is practically unknown in the United States. As made by the Allgemeine Co., this meter consists of a hand-wound 13-day clockwork, with a cyclometer dial reading up to 999 hours. A small lever arrests the motion of the balance wheel when no current is flowing. When current flows, an electromagnet withdraws the lever and allows the clock to run. The electromagnet may be in series with the current, or in parallel; in the latter case the main switch for controlling the load must be in front of the time meter. A form without electromagnet has a single-pole switch built in the meter for controlling the load. The closing of the switch mechanically releases the clockwork. Another type of time meter is made for street-car service, for recording the number of hours' use of the current, as a check on the motorman. As the readings are generally taken several times during each trip, a dial for reading minutes is also provided.

An interesting form of time meter is made for determining the number of hours' use of such constant-current devices as laundry irons, electric heaters, etc., as a basis for giving a discount from the total bill for lighting and heating, as shown by the usual supply meter on the whole installation. The release of the clockwork in this "reimbursement meter" is made by the expansion of a wire which is heated by the current. Connections to the meter are made by plug contacts, so that the meter may be readily inserted in series with the heating device. The weight of this meter is 1 pound 5 ounces; diameter, 3 inches; and list price, $4.28. It is made in 1, 3, 5, 7.5, and 10 ampere sizes. The winding of the clock is done by

the consumer, it being to his interest to keep going a meter which secures him a substantial discount on part of his bill.

TWO-RATE AND MAXIMUM-DEMAND METERS.

A. E. G. two-rate meters are made in two forms. The first has an electromagnetic device for coupling the meter spindle to one or the other of the two registers, and the change-over is effected by a separate pendulum clock, either hand or electrically wound. The other form has the clock built in the meter, and the change-over is effected mechanically. The maximum-demand meter has a train of gears that is connected to the meter spindle at intervals either by a separate clock or by a built-in clock. The gearing moves an index around the maximum-demand dial. When the clock releases the gearing the carrier which has been pushing the index returns to its initial position, leaving the index at the highest point reached.

FUSSNER UND FORDERMANN.

The firm of Fussner und Fordermann is located in Godesburg, a suburb of Bonn on the Rhine. It acquired the electrical-instrument business of the Elektrische und Magnetische Apparatebau Gesellschaft, whose product now consists mainly of switchboards and control apparatus.

Switchboard and portable instruments are made in moving-coil, moving-iron, dynamometer, and hot-wire types. In addition to the usual form of moving-coil system, the Schortau system is used for switchboard instruments. In this construction a radially wound aluminum disk moves in the single air gap of a permanent magnet. The disk acts as coil support and damping frame. The list prices of instruments with this system are slightly lower than those of instruments otherwise the same, but having the usual construction.

The standard construction of this firm's moving-iron switchboard instruments includes gravity control, spring control being listed as an extra. Air damping is used. The firm uses air damping in hot-wire instruments also, the reason given being that the usual damping magnet is sometimes objectionable because of the effect of its stray field on neighboring apparatus.

Other electrical instruments made by this firm include small watch-form voltmeters and ammeters, both moving-coil and moving-iron types, portable insulation testers, and demonstration instruments.

S. GUGGENHEIMER.

The works of Dr. S. Guggenheimer at Nuremberg produce a large line of switchboard and portable instruments. Moving-iron instruments, for example, are made in eight sizes, ranging from 80 to 550 millimeters (3 to 22 inches) in diameter, in addition to sector and profile forms. All are air damped except the 80-millimeter instruments. Mr. Guggenheimer considers that by using suitable die castings the cost of air-damped instruments can be kept practically as low as that of undamped instruments, and that there is no reason for the existence of the latter. Gravity control is standard, spring control being supplied on order at an extra cost.

Direct-current moving-coil instruments have the pole pieces held in position by casting nonmagnetic alloy around them. The standard ammeter-shunt drop is 60 millivolts, the indications of the instrument being said to be independent of temperature. When temperature errors can be tolerated, and the current to be measured is large, the drop can be made as low as 15 millivolts.

Hot-wire instruments have air damping, the presence of damping magnets being objectionable in some cases. The "precision millivoltmeter for direct and alternating current" is a thermal instrument, having a permanent-magnet moving-coil system. The terminals of the coil are connected to two opposite corners of a Wheatstone bridge made up of four thermocouples. The voltage to be measured, either direct or alternating, is applied to the other two corners of the bridge. The bridge is so balanced that the line current can not enter the moving-coil circuit, nor can the thermal currents pass out to the line. An adjustable rheostat marked in temperature degrees is used to correct for room temperature changes. The full reading requires 225 millivolts at the instrument terminals, and a current of 1 ampere. For higher current ranges, up to 2,000 amperes, external shunts are used.

Two types of switchboard wattmeters are made, one of which is astatic, having two pairs of fixed coils and two mechanically connected moving coils. These instruments are thus unaffected by uniform stray fields, and do not require reversal of the current when checking by direct-current standards. The same construction is used in the portable voltmeters and wattmeters on the dynamometer principle. Portable wattmeters with two or three current ranges have a knob which is turned to change the range; the maximum current and the multiplying constant appear in window openings in the scale plate as the knob is turned.

The "universal measuring instrument for direct and alternating currents" is designed to make all practical electrical measurements. It consists of an astatic dynamometer wattmeter, a voltmeter, and an ammeter, built into a single case. In the lid of the case may be fitted a frequency meter of the vibrating-reed type and a slide-wire bridge. The instruments are of the profile (edgewise) pattern, with scales nearly 7 inches long.

Registering instruments for direct current have two strong permanent-magnet moving-coil systems, each carrying a very light grooved aluminum pulley. A fine wire runs over the two pulleys and draws the pen in a straight line across the paper. In a similar way, the registering wattmeter for polyphase use has two systems coupled in the same way, the torques of the two being thus mechanically added.

HARTMANN & BRAUN A. G.

The works of Hartmann & Braun A. G. are located in Frankfort on the Main. The company was formed in 1884 for the manufacture of electrical instruments, which form the larger part of the output at the present time.

EQUIPMENT AND METHODS.

The work is carried on in a number of large brick buildings several stories high. Most of the machines and tools are of German make, although some Brown & Sharpe and Cincinnati milling machines

are in use. Electrical power is bought, and the machines are driven by line and counter shafting, the line shaft in each room being driven by a direct-current motor. The procedure in one of the buildings, taken as an example, is as follows: Rough castings are received on the ground floor and the rough edges and projections are ground off. They are then sent up to the floor above to be turned, drilled, etc., and then to the next floor to be enameled, plated, or otherwise finished. The arrangement of the machines and the method of carrying on the work are orderly and systematic, and the welfare of the workmen has been considered. For example, dust-producing machines, for grinding, buffing, etc., are fitted with exhaust connections to prevent dust in the workrooms.

The governing idea in the manufacture seems to be to make the best possible jigs and tools, even at high cost, in order to save time subsequently in the production and to secure the best possible product. As an instance, the scales of precision instruments are drawn on very accurate circular dividing engines. These scales are very good, the lines being fine and uniform. Many ingenious methods are in use, some of which for business reasons can not be described here. The following process, however, may be given as an illustration:

CONSTRUCTION OF MOVING COILS.

Moving coils are made, as a rule, of aluminum wire, to reduce the wear on pivots and jewels and to reduce the moment of inertia. A very interesting process is used in the construction of millivoltmeter coils. Such coils have sometimes been wound with square or rectangular wire, which has electrical advantages for this case. However, such wires are much more troublesome to wind, and it is not easy to make the wire lie close to the frame. Hartmann & Braun wind round silk-covered aluminum wire on the aluminum frame, and then put the coil in a press which flattens the wire. The pressure is so great that the wires are slightly embedded in the aluminum frame; nevertheless the insulation between the separate turns and between the wire and the frame remains intact. In single-layer coils the cross section of the wire after pressing is nearly square; in two-layer coils the section becomes approximately an isosceles triangle, the bases in one layer being next to the frame, in the other away from the frame. This patented construction gives a highly efficient coil. All direct-current instruments have the two spiral springs at the upper end of the coil.

LABOR—WELFARE WORK.

About 550 employees are engaged in the work, of whom less than 10 per cent are girls. The latter are engaged chiefly in winding coils. The officials, engineering staff, and clerical force number about 250, making a total personnel of 800. The working day for shop employees is 9 hours, except Saturday; 53 hours constitute a week's work. The office force, engineering staff, etc., have a somewhat shorter day. A notable difference between American and German customs is seen in the length of the "noon hour," which in Hartmann & Braun's works is from 12 to 2. Most of the mechanical work is paid for on a piecework basis. The average instrument maker earns about 7 marks ($1.67) per day.

Strikes and similar difficulties with the workmen are said to be practically unknown. The firm has carefully considered the welfare of its workmen. A well-equipped machine shop, under a capable instructor, trains apprentices to do accurate work. A small library is available to the apprentices. Bathrooms are provided, available for a nominal fee. A "first-aid" room is equipped with surgical instruments, bandaging material, etc., ready to deal with accidents such as can not be entirely avoided. By way of preventing accidents, shields and warning notices are used. Dangerous parts of machines, such as the back gears of lathes, are painted red to remind the user. A cabinet in which insulation tests of instruments up to 200,000 volts are carried out is made safe by interlocking the door of the cabinet and the switch in the low-voltage primary circuit of the transformer. The circuit can not be closed until the door is closed.

The apparatus manufactured includes ammeters, voltmeters, wattmeters, and other indicating instruments in switchboard and portable forms, as well as a large variety of electrical apparatus for scientific purposes. Space is not available to enumerate all the types, but some particular ones of special interest will be briefly described.

THREAD POINTER—MULTIPLEX INSTRUMENTS.

Precision portable direct-current voltmeters and millivoltmeters are equipped with a novel form of index called the "thread pointer." A fine stretched wire replaces the usual knife edge, and a small translucent screen is carried by the pointer. The image of this screen in the scale mirror gives a bright background against which the blackened wire and its image are clearly seen. It is claimed that this form of pointer enables one to make more accurate readings and is less fatiguing than the usual form.

In addition to the usual form of precision millivoltmeter and shunt, Hartmann & Braun make duplex, triplex, and quadruplex millivoltmeters and shunts in order to supply the need for a large number of ranges with the minimum amount of apparatus. A "multiplex" millivoltmeter has several ranges—for example, 30, 60, 150, and 300 millivolts—all of which are compensated for temperature. A multiplex shunt does not differ in principle from the usual form; it is designed to carry the current which gives the maximum drop of potential required by the millivoltmeter for full deflection—300 millivolts in the example above given. This shunt thus serves for as many current ranges as the millivoltmeter has potential ranges. In changing from one range to another, with a given shunt, the main current is not disturbed, as only the potential cable needs to be shifted. Thus the readings may be kept well up on the scale at all times. By a special arrangement of circuits of different temperature coefficients the multiplex millivoltmeters are compensated for temperature on all ranges of 60 millivolts and higher. The care which is taken in this matter may be appreciated from the statement that instead of assuming an average figure for the temperature coefficient of the copper wire used the temperature coefficient of each lot of wire is carefully determined.

SELF-CONTAINED AMMETERS—SWITCHBOARD INSTRUMENTS.

Precision portable direct-current ammeters are made with from one to four ranges, self-contained, up to 200 amperes. These instruments have a common terminal and as many other terminals as the ammeter

has ranges. There are no moving contacts in the millivoltmeter circuit and the one point of contact which is shifted in changing the range is in the line, and if it is of variable resistance it can not affect the accuracy of the readings. The principle is that of the Ayrton-Mather universal galvanometer shunt. It is somewhat surprising that many makers have overlooked the advantages of this arrangement, of which there is only one instance, a very recent one, on the American market.

A much larger number of styles and sizes of switchboard instruments is made than is the case with American makers. For example, seven sizes of round-pattern direct-current ammeters and voltmeters are made, ranging from 70 to 530 millimeters ($2\frac{3}{4}$ to 21 inches) in diameter. Round-pattern moving-iron ammeters and voltmeters are made in three sizes, all having air damping.

HOT-WIRE INSTRUMENTS—USE OF PLATINUM-IRIDIUM.

Hartmann & Braun were pioneers in the manufacture of hot-wire instruments. The first type, invented by Cardew, was of very inconvenient form; the type introduced by Hartmann & Braun used a working wire about 6 inches long and was an improvement over the Cardew in other respects. In recent years a radical improvement has been made in Hartmann & Braun hot-wire instruments by substituting platinum-iridium for platinum-silver as the material of the working wire. Platinum-iridium can be run at a much greater temperature elevation and its coefficient of expansion is appreciably less than that of platinum-silver. As a result, the new instruments are much less affected by changes of room temperature and the annoying zero shift of the older instruments is greatly reduced. The new instruments are made as ammeters and voltmeters, in switchboard and portable forms.

UNSHUNTED AMMETERS FOR WIRELESS TELEGRAPHY.

An interesting recent development is the unshunted hot-wire ammeter for the highest frequencies used in wireless work. Ordinary shunted hot-wire ammeters, when used for current at 1,000,000 cycles, show very large errors. The new "hot-strip" ammeter has a group of thin platinum-iridium strips arranged as elements of a cylinder, the ends of the strips being connected to two copper disks, which are part of the line terminals. The current passes straight through the instrument, avoiding loops, and since the strips are symmetrically placed there is no tendency toward change of distribution of the current due to change of frequency. The uppermost strip is used as the expansion element in place of the usual wire. These ammeters are made up to 300 amperes.

FREQUENCY METERS—HIGH-FREQUENCY GENERATORS.

Frequency meters on the resonance principle, with vibrating reeds, are made in a great variety of forms. For use in connection with wireless telegraphy they are now made up to 1,500 cycles per second. The resonance principle is also applied to the construction of tachometers, either for direct attachment to the machine for showing the speed in revolutions per minute or for operation at a distance

by current from a small magneto generator connected to the machine. A natural outgrowth of the manufacture of these magneto generators is the high-frequency generator, which is made for an output of several kilowatts and a maximum frequency of 7,000 cycles per second.

WIRE FILAMENTS.

Among the special materials supplied by Hartmann & Braun should be mentioned their fine wires ("wire filaments"), which are made down to 0.015 millimeter (0.0006 inch) in diameter. These are supplied in gold, silver, platinum, and other pure metals, and also in alloys, a total of 18 materials being listed.

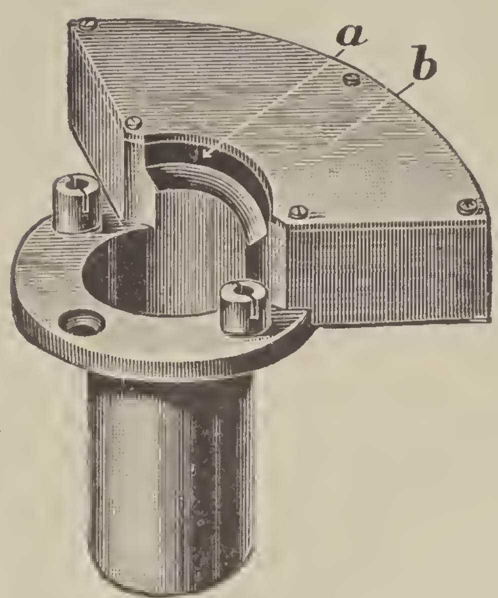

Fig. 4.—Ordinary air-damping box.

R. KIESEWETTER.

The works of R. Kiesewetter, of Leipzig, produce switchboard and portable instruments and accessories. Electromagnetic instruments have air damping, the patented construction employed being worthy of special mention. It consists of a sector-shaped box in which swings an aluminum vane. A construction which is employed by some instrument makers is shown in figure 4. The vane is attached to the shaft by an arm which passes through

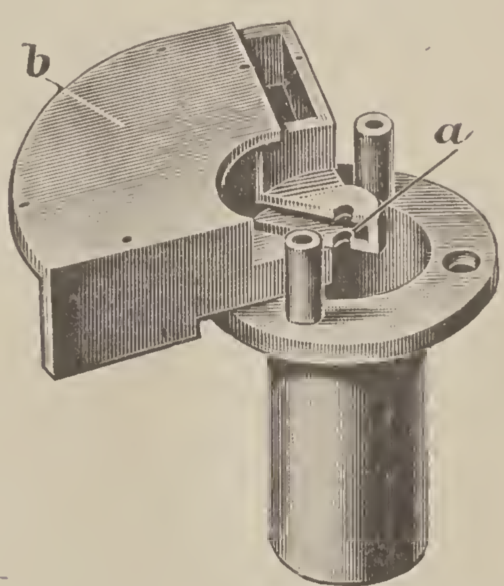

Fig. 5.

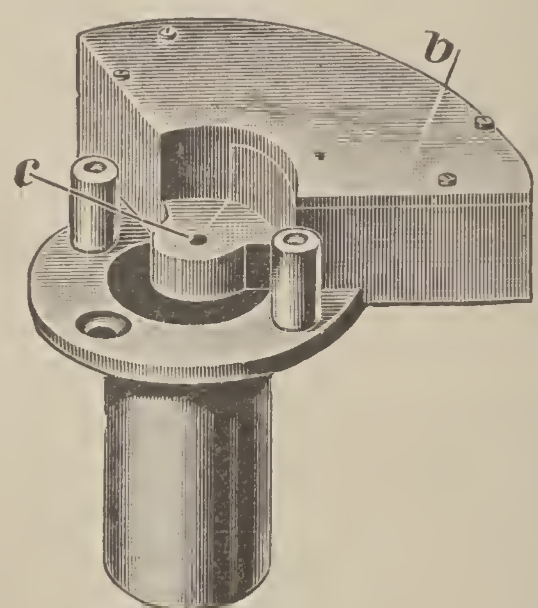

Fig. 6.

Kiesewetter air-damping box.

the slit *a*. It is evident that leakage of air through this slit reduces the efficiency of the device. To avoid this leakage, Mr. Kiesewetter uses the construction shown in figures 5 and 6, the former showing the two halves of the box separated to show the interior. The arm which carries the vane swings within an extension of the damping chamber, and the only place where leakage can occur is around the shaft. It is evident that the leakage will be much less than with the form shown in figure 4. As the box is composed of die castings it is not more expensive than the usual form.

POCKET INSTRUMENTS—COIL-WINDING MACHINES.

A specialty is made of pocket voltmeters, ammeters, and lamp testers. In even the cheapest voltmeter, selling for considerably less than a dollar, the coil is wound with silk-covered wire, and the scales are individually drawn. The voltmeter coils are wound to have the same length of wire, not necessarily the same number of turns. By this means the resistance is said to be kept more nearly uniform. Special winding machines were made for the work, each consisting of a head driven by a direct-current motor. A treadle operates a simple strap key which makes and breaks the motor circuit. The wire to be wound runs once around a grooved pulley, one turn of the wire around the pulley being 0.1 meter (3.937 inches) in length. On the same spindle with the grooved pulley is a pinion which meshes with a gear, giving a 10 to 1 reduction of speed. This gear is on the shaft of a revolution counter, and one turn of the shaft, which records 1 on the lowest dial, corresponds to 1 meter of wire wound.

The design of the pocket voltmeters is such that no instrument takes over 0.1 ampere for full deflection. This is important when the voltmeter is to be used for determining the voltage of primary batteries having appreciable internal resistance.

LAND UND SEEKABELWERKE A. G.

The Land und Seekabelwerke A. G. is located at Nippes, a suburb of Cologne; its chief products, as the name indicates, are electrical cables of all sorts. It also manufactures electrical instruments, having purchased the business originally established at Hanover by Dr. R. Franke.

A complete line of resistance apparatus is made, using manganin wire and sheet. A distinctive feature of some of this apparatus, including potentiometers, is the use of contact blocks arranged in straight lines instead of the usual circles. Other apparatus made by this company includes cable-testing sets, fixed and variable inductances, condensers, galvanometers and their accessories, and the Franke curve tracer.

The line of direct-current apparatus includes moving-coil instruments in two constructions. The older construction, due to Dr. Franke, has a circular coil moving in spherically recessed pole pieces, with a spherical inner core. The pole pieces are threaded and screwed into a brass casting which also carries the inner core and forms the bearings for the moving coil, thus giving a very solid construction. This form is used for switchboard instruments and for moderate-priced portables. For the best-grade portable instruments the rectangular coil, as used by nearly all makers, is employed. These latter instruments have a feature intended to facilitate accurate reading. The usual mirror is used to prevent parallax, and a frosted band, in the form of a circle arc, is etched on the cover glass. In use this band appears in the mirror as a bright background against which the image of the needle appears. Moving-iron instruments are also made, in switchboard and portable forms, air damping being used.

SIEMENS & HALSKE A. G.

The firm of Siemens & Halske A. G., of Berlin, claims the distinction of being the oldest electrotechnical firm in the world, having

developed from a small business started in 1847. The products of the various factories of this firm and its associated companies cover the whole field of electrical engineering. The present description is limited to electrical measuring instruments, which form a part of the output of the large factory called the Wernerwerk, in Nonnendamm, a suburb of Berlin. The processes of manufacture are thoroughly organized. The raw materials are machined in large quantities into standard parts, which are stored, and are drawn upon as required for assembly.

MOVING-IRON AND MOVING-COIL INSTRUMENTS.

Moving-iron switchboard ammeters and voltmeters are made on the solenoid and plunger principle, in contrast to the more generally used repulsion principle. A disk of specially treated soft iron is caused to rotate so as to enter a flattened solenoid, when current flows through the latter. The smallest of these instruments, with base 135 millimeters (5.3 inches) in diameter, has air damping, and in ordinary ranges lists at about 20 marks ($4.76). By the use of pressed sheet-iron bases the weight is kept low (1⅓ pounds). In spite of the low price these instruments are well finished and have individually drawn scales. By varying the relative position of the iron disk and its solenoid for the zero position, the character of the scale of the voltmeter is made quite different from that of the ammeter. The graduation of the voltmeter scale is open near the working point, about two-thirds of the maximum voltage, and is crowded below one-half of the maximum. The ammeter scale is designed to be as nearly uniform as possible.

Shunts for moving-coil direct-current switchboard ammeters for currents of several hundred amperes and above have rods of resistance material instead of strips. Round pattern moving-coil instruments are made up to a diameter of 690 millimeters (27 inches).

SWITCHBOARD WATTMETERS—SHUNTED DIRECT-CURRENT WATTMETER.

Switchboard wattmeters are made on the dynamometer principle and also on the induction ("Ferraris") principle. In addition, a special direct-current wattmeter is constructed with an electromagnet excited by a voltage winding; a moving coil swings in the air gap, as in a permanent-magnet moving-coil ammeter or voltmeter. This coil is connected to the terminals of a current shunt having a full-load drop of 60 millivolts. The advantage of this construction is the strong torque, namely, 10 millimeter-grams. Because of the strong field in which the coil moves, external stray fields exert a relatively small influence on the readings. It is stated that the hysteresis error resulting from variations of 20 per cent above and below normal voltage does not exceed 0.4 per cent. The error following a temporary interruption of the circuit is said to be 0.8 per cent.

INDUCTION INSTRUMENTS—INSTRUMENT TRANSFORMERS.

The induction principle is used in the construction of ammeters and voltmeters for switchboard use at a definite frequency. The switchboard frequency meters are made on the vibrating-reed principle.

As accessory apparatus for the preceding, current transformers are made in ranges up to 30,000 amperes; for currents up to 500 amperes, current transformers are made for operation on circuits up to 80,000 volts. The variety of styles and sizes is very great. Potential transformers are made in similar variety up to 80,000 volts.

PORTABLE AND LABORATORY DIRECT-CURRENT INSTRUMENTS.

The preceding principles are also applied to the construction of portable and laboratory instruments. In the line of permanent-magnet moving-coil instruments one type calls for special mention. By the use of an aluminum wire coil of small radius a system is made which has such good electrical properties that it may be made up as a combined millivoltmeter and voltmeter and still give good results for either use. As a rule, such combination instruments have a relatively low resistance per volt when used as voltmeters and a relatively high drop when used as ammeters. In the present case, when the instrument is used as a voltmeter, the resistance is $333\frac{1}{3}$ ohms per volt, or about three times as high as that of the usual portable voltmeter. When used as a millivoltmeter, the drop for full deflection is 45 millivolts, with an internal resistance of 10 ohms; the instrument is compensated for room temperature changes for either use. This low millivolt drop considerably reduces the size, weight, and cost of the shunts. The latter are made exclusively of manganin. The same instrument system forms part of a "technical potentiometer arrangement," which has an arrangement of circuits by which the moving-coil instrument may be checked at one point by reference to a standard cell. By means of a magnetic shunt, any necessary correction may be made for the effect of stray field or other source of error, so that the reading at the check point of the scale is correct at the given time and place. The instrument will then read correctly at the given time and place, within the limit of accuracy of the graduation of the scale, so long as the disturbing influences remain constant. This apparatus is especially designed as a standard instrument for those cases where a potentiometer is inadvisable. It is arranged to measure voltage in several ranges, and also current, with suitable shunts.

ELECTRODYNAMOMETER INSTRUMENTS.

In addition to a "laboratory type" of dynamometer ammeter, voltmeter, and wattmeter, which has been made for a number of years, a new model has been brought out recently. These instruments have metal cases, and are smaller and lighter than the laboratory type; they are intended for use in practical testing, especially in connection with current and potential transformers. The wattmeter and ammeter of this type are made in 5-ampere range only.

Several types of dynamometer wattmeter are made for special uses. One type resembles in outside appearance the direct-current portable instrument, but has a tube covering the strip suspension of the moving coil. This suspension greatly increases the sensitiveness, so that full deflection requires only 1.2 watts. A similar instrument with a shunted current coil gives full deflection for 6 watts, and is especially intended for measuring the power lost in the potential circuits of alternating-current meters. For measuring power at very low power

factors a large astatic wattmeter with strip suspension is made in several ranges. These will give full deflection for power factors as low as 2 per cent, and are intended for measuring the losses in cables and in inductance coils. Such a wattmeter with a 1-ampere current range gives full deflection for 0.0015 watt.

A line of portable instruments is made for work not requiring the highest accuracy. The systems employed are substantially those used in round-pattern switchboard instruments, parallax mirrors not being supplied. These instruments are made on the moving-coil, moving-iron, and induction principles. The vibrating-reed principle is also used in portable frequency meters.

CURRENT TRANSFORMERS—GALVANOMETERS.

Current transformers for use with portable and laboratory instruments have iron cores of liberal cross section without joint. The figures given for ratio and phase angle of these precision transformers are very good and justify the extra trouble and expense of the construction used, when the transformers are to be used on accurate work.

Moving-coil galvanometers are made in a variety of forms, from a simple portable to a sensitive reflecting instrument. This company is to be commended for stating in its catalogue all necessary data in regard to its reflecting moving-coil galvanometers, namely, coil resistance, total resistance for critical damping, period, and sensitivity. No other maker states all four, to the writer's knowledge.

RESISTANCE APPARATUS—POTENTIOMETERS.

Resistance standards, boxes, etc., are made after the Reichsanstalt models, using manganin for all but very high resistances, where constantan is superior. Potentiometers are made in two forms—the Raps and the new Feussner. Apparatus is made for testing the magnetic properties of iron, for the shop and field testing of resistance and insulation, and for the measurement of inductance. The Siemens-Blondel oscillograph is of the type employing a fine wire loop stretched in the field of an electromagnet and carrying a light mirror.

SIEMENS-SCHUCKERT WERKE.

The Siemens-Schuckert Werke at Nuremberg construct dynamos, motors, and other electrical equipment, including electric meters, of which the company is one of the largest makers in the world. The daily production exceeds 1,000 meters.

DIRECT-CURRENT WATT-HOUR METERS.

The G5 direct-current watt-hour meter has circular field coils and a spherical armature having three coils 120° apart, connected as a drum winding. The three-part commutator is not soldered to the armature leads, but the connection is made by three plated steel springs. Damaged or worn commutators can thus be quickly replaced and afterwards repaired at the station. The brushes are of silver strip, faced with gold wire where they touch the commutator,

and may be readily removed and replaced without altering the tension. The armature shaft is tapered at the bottom and has a renewable steel pivot. The removal of the jewel screw also removes the pivot. Oil is used in the bearing, which is constructed so as to retain the oil while the meter is being transported. An iron plate is used to screen the drag magnets from the stray field of the series coils. The series resistance is wound on porcelain spools. Cyclometer dials are standard, the ordinary pointer dial being supplied only on special order. The number wheels are advanced suddenly by the falling of a weight raised by the spindle of the lowest wheel. The torque of the G5 meter is given as 85 millimeter-grams.

AMPERE-HOUR METERS.

The A2 meter is a direct-current ampere-hour meter, having a flat disk armature with three coils revolving between strong permanent magnets, which furnish the driving and braking field. The armature resistance is about 33 ohms, so that small changes of brush contact resistance cause no appreciable errors. The shaft is fitted with a removable pivot which comes away with the jewel screw when the latter is removed. Oil is used in the jewel bearing. The full-load speed is about 100 revolutions per minute, and the torque about 90 millimeter-grams. The current to be measured flows through a shunt contained in the meter, around which the armature circuit is connected. The drop of potential at full load is about 1.5 volts.

INDUCTION WATT-HOUR METERS.

The W10 meter is a compact low-priced meter for alternating currents. In general appearance it resembles the small round meters brought out in the last few years in the United States. The diameter of the case is about 6 inches and the weight 7 pounds. The following figures are given for the W10 meter: Full-load torque, 55 millimeter-grams; weight of moving element, 30 grams; full-load loss in series coil, 2 watts; shunt loss, 1 watt. This meter is furnished only with cyclometer dials.

The W2 meter for alternating currents is a larger form than the preceding and has a special feature for improving the light-load accuracy. The lower bearing is supported on a flat spring, which carries a small iron armature. An electromagnet near the armature is connected in the potential circuit and vibrates the lower bearing, reducing the friction. Up to 50 amperes the weight of this meter is 13 pounds; above 50 up to 300 amperes, 20 pounds. The following data are given for the W2 meter: Full-load torque, 75 millimeter-grams; weight of moving element, 40 grams; full-load loss in series coil, 3 watts; shunt loss, 1.2 watts.

The D5 meter for three-phase four-wire circuits has two disks on one shaft. Two motor elements act on the lower disk and one motor element and the two drag magnets on the upper disk.

The D6 polyphase meter has two disks on one shaft; the lower is acted on by one motor element and the upper by the other element and the two drag magnets. The following figures relate to the D6 meter: Full-load torque, 110 millimeter-grams; weight of moving element,

80 grams; full-load loss in each series coil, 2 watts; loss in each potential coil, 1 watt.

SUBTRACTION ARRANGEMENT FOR WATT-HOUR METERS.

All types of Siemens-Schuckert meters may be fitted with a "subtraction arrangement." This is intended to record all use of current in excess of a specified load for which a contract rate is paid. The arrangement consists of a differential gearing, one side of which is driven by a clock at a constant speed, depending on the amount of the specified load. The other side is driven from the worm on the meter spindle, which also drives a register showing the total current used. The planet wheel of the differential gearing drives a second register only when the speed of the meter spindle exceeds the speed corresponding to the specified load. A ratchet wheel and pawl allow the second register to run forward only. This type of meter is termed a "depassement" meter by French makers.

MAXIMUM-DEMAND METER.

The polyphase meter with maximum-demand arrangement contains a clockwork driven by a small induction motor, the rate being controlled by a balance wheel. A train of gearing is driven from the meter spindle and is arranged to rotate a gear wheel having a projecting pin which drives the maximum-demand index forward over a scale. At intervals, say every 15 minutes, the clockwork releases this gear wheel and a spring returns the wheel to its initial position. The index remains by friction in the highest position reached until set back by hand; the scale is marked to read the maximum demand.

VEREINIGTE ELEKTROTECHNISCHE INSTITUTE.

The Vereinigte Elektrotechnische Institute (Veifa Werke) is located in Frankfort on the Main. In addition to a large output of electromedical apparatus, including X-ray apparatus, a line of switchboard and portable electric instruments is made.

Moving-iron instruments are all made with spring control, and all sizes from 130 millimeters (5 inches) diameter up have damping. The 5-inch instrument has damping of a novel form. Two damping vanes 180° apart move in the annular space between the cylindrical case and a cylindrical inclosure around the solenoid. This makes a special damping box unnecessary. In spite of the low price of these 5-inch instruments—\$3.84 to \$5.76—the scales are individually made on circular dividing machines. The 200-millimeter (8-inch) moving-iron instrument has oil damping. Permanent-magnet moving-coil instruments are made with the usual form of magnetic system and coil, for currents up to 1,000 amperes.

Hot-wire instruments supplied by the Veifa Werke have a device which short-circuits the working wire at a predetermined overload, to protect it from damage. Ammeters for direct connection in high-voltage circuits (up to 12,000 volts) are mounted on porcelain insulators tested to 50,000 volts. Other products include watch-form ammeters, voltmeters, and lamp-testing instruments, as well as milliammeters designed for electromedical work.

ITALY.

C. G. S. ELECTRICAL INSTRUMENT CO.

The C. G. S. Electrical Instrument Co. (formerly C. Olivetti & Co., of Ivrea) is located at Via Broggi No. 4, Milan. It occupies a three-story stone building, on the first floor of which are the departments for machine work, die casting, and plating. The second floor is occupied by the winding and assembly departments, and also by the calibrating and testing laboratories. The third floor contains the offices.

EQUIPMENT AND METHODS.

Nearly all the machine tools are of American make, including Brown & Sharpe milling machines, Reed lathes, Prentice lathes, Pratt & Whitney lathes and drills, Norton grinding machines, Bliss presses, Gould & Eberhardt shapers, and Cincinnati milling machines. The high quality of American tools is fully appreciated by this firm.

The American system of interchangeable parts is used in all Olivetti instruments. The tolerance allowed on general work is plus or minus 0.02 millimeter (0.0008 inch); for some parts the limits are still closer. The company has developed a die-casting process which greatly reduces the work required on many of the instrument parts; it is said that the castings frequently come out more accurate than the limit of tolerance above mentioned. All Olivetti instruments are damped; for all types of indicating instruments except the moving-coil permanent-magnet type, this is accomplished by an air-damping box. The use of die castings is of especial advantage at this point, and enables the production of a damped instrument at a moderate price.

OUTLINE OF PRODUCTS—RECORDING INSTRUMENTS.

The product of the company consists of indicating and recording electrical instruments and instrument transformers. Round-pattern switchboard instruments are made of 15, 16, 18, 20, 22, 30, 41, and 60 centimeters (6 to 24 inches) diameter, to meet the various demands of home and foreign trade. Voltmeters, ammeters, and wattmeters are included, of electromagnetic, moving-coil, permanent-magnet, electrodynamometer and hot-wire types. An important part of this company's product, by which it is perhaps best known, is its large variety of recording instruments. These are made in round pattern (35 centimeters diameter) with hot-wire movement; in rectangular form (two sizes) of hot-wire, electromagnetic, and moving-coil types, and a large rectangular pattern operating on the relay principle, which is furnished with moving-coil or with electrodynamometer

movement. Potential transformers are made up to 80,000 volts, and current transformers are regularly supplied up to 6,000 amperes; on order, they are made up to 30,000 amperes.

SUMMATION WATTMETERS—PORTABLE INSTRUMENTS.

An interesting type of instrument which seems to be made only by this company is the "summation" indicating (or recording) wattmeter, which enables the total power of a number of alternators to be indicated on a single dial or recorded on a single chart. A recording wattmeter of this type is in operation in Milan, which traces on a single chart a record of the combined output of 19 alternators.

Portable instruments are made in two grades, namely, a "portable" at a moderate price for commercial use, where an accuracy of 1.5 per cent is sufficient, and a "control" instrument for use in laboratory work, where a higher accuracy (0.5 to 0.7 per cent) is desired. These two grades are made in all the types specified above for switchboard instruments.

Indicating instruments also are made on the relay principle for switchboard use and (in a different form) for laboratory work. Another useful instrument supplied by the Olivetti Co. is the rolling planimeter, which enables the diagrams drawn by their rectangular recording instruments to be rapidly integrated. At a single operation a length of chart of 3 to 4 meters (or longer, if a longer table is used) can be integrated, and the construction is such that the result may be read in kilowatt hours for recording wattmeters of all ranges.

LABOR CONDITIONS.

The company's force numbers about 150 employees; the working day consists of 8 hours for the engineering and clerical staff, and 10 hours for the workmen. Girls are employed for some of the winding operations, and the more delicate work of assembly; they also assist in some of the testing work and in the drawing of instrument scales. The average wages are as follows: First-grade mechanics, a minimum of 8 francs ($1.54) a day, with opportunity to earn, say, 9 francs ($1.74) by exceeding a certain limit of work accomplished; second-grade mechanics, 4 to 5 francs ($0.77 to $0.97) a day under a similar arrangement; the minimum for male employees is 3 francs ($0.58) for boys; girls earn from 2 to 3 francs ($0.37 to $0.58) per day. The company is in position to select its employees, and has no trouble due to disaffection on their part. The company has never had a strike. The cost of living is high in Milan, being not far below that of Paris. In the last year or two wages have been increased by the company about 25 per cent, and the prospect is that further increases will be required.

SOURCES OF MATERIALS—MARKETS.

The company draws its supply of raw materials from various sources. Insulated wire, copper, and porcelain parts are bought from Italian sources; other insulating materials principally from Germany or France. Sheet steel is bought from England, in spite of the higher cost as compared with German steel. The company considers the

English steel of higher quality for its purposes. Instrument jewels are bought in Italy, where the business of cutting jewels is said to be very extensive; sapphire, garnet, and agate being imported in the rough and exported as finished jewels to England, Germany, Switzerland, and France for use in watches and electrical instruments. The principal source of supply of the raw material is said to be Australia; American electrical instrument makers, however, usually refer to Ceylon as the source of the sapphire they use.

The duty on English steel sheets imported into Italy is stated to be 15 to 17 francs ($2.90 to $3.28) per 100 kilos (220.6 pounds). The company is aware of the good quality of American steel, but has had no offers from American makers, who maintain no stock in Italy. In general, the makers of dynamos, motors, and transformers in Italy are said to obtain their steel from German firms who maintain branch houses in Italy with large stocks. The company has obtained insulating varnish and transformer oil from America, but has found it difficult to buy these American materials because there is no agent in Italy and no stock is carried. The company states that the difficulties in the way of buying directly from American makers are: (1) The distance; (2) American makers desire to sell catalogue (standard) material only, and do not take the time and trouble to study the special needs of foreign customers. They consider it very important for American firms who wish to sell goods to Italian consumers to quote "franco" (free) in Italy. German firms will quote f. o. b. customer's works if requested. In general, American firms should quote "franco vagone" (free on cars) at the customer's shipping address, with freight and duty paid.

The company has tried French and German magnets, but has found the quality to be less satisfactory than that of magnets made in its own shops, and it is therefore now making all of its magnets. The most satisfactory steel is obtained from England. American makers of magnet steel maintain no stock in Italy, and have no agents, so far as the company is aware. The company's product is sold largely in Italy, and a considerable amount is exported to Switzerland, France, and Sweden.

COMPAGNIA ANONIMA CONTINENTALE GIÀ J. BRUNT & C.

The Compagnia Anonima Continentale già J. Brunt & C. was founded in 1846 by an American, John Brunt. It makes all kinds of apparatus used in the manufacture of gas, including gas meters. Other products of the company include water meters, lighting fixtures for buildings and for street illumination, and electric meters, of which latter about 3,000 to 3,600 are made annually.

The company's buildings are located in Milan at 41–43 Via Quadronna, and are of stone. The equipment for the manufacture of electric meters was procured almost entirely in Europe; the same is true of the materials. The company has made no attempt to secure material or equipment from the United States.

PIECEWORK PLAN, WITH MINIMUM WAGE GUARANTEED.

The total number of employees varies from 300 to 500, according to the conditions of business; of these, about 30 men are now employed in the manufacture of electric meters. No women are employed in the

factory, but some of the lighter work, such as the winding of coils, is sent out to be done at home by women, usually by the wives of men employed in the works. The working day is 10 hours; the minimum daily wage for a skilled man is 6 to 7 francs ($1.16 to $1.35). The employees of each department of the works have a union of their own, but the operation of this union is quite different from that of trade-unions in the United States. For example, the men in the foundry are dealt with by the firm as a unit; the castings are paid for on the piecework plan, but a certain minimum daily wage is guaranteed. Defective castings are not paid for. The work is figured in large lots, and any surplus above the guaranteed minimum is divided equally among the men. For example, a lot of castings will be made by the men of the foundry and the pay for the lot, on the piece basis, is 1,000 francs. The time required is such that the men receive as their guaranteed minimum 700 francs. The remainder, 300 francs, is divided equally among the men, regardless of their time of service with the company. This plan has two marked advantages: First, it incites the men to do their best work in order to avoid defective castings for which no pay is received; second, it eliminates shirking, as each man is watched by others; a shirker is put out of the factory by the workmen themselves. Before this plan was put into effect about 40 per cent of the castings were defective; now only about 2 or 3 per cent are defective.

There are said to be no trade-unions here of the kind known in the United States and England, and no strikes. The workmen in each department of a factory in Milan have a representative in a central body which meets to consider requests and discuss matters of interest. All the employees of the Brunt Co. are insured by the firm against accident, and the men have a mutual-benefit fund from which aid is given in case of sickness. This fund is maintained by small assessments levied on the wages; also by fines imposed for tardiness, loss of tools, or unwarranted damage to tools or material, and so on.

The products of the company are in the main absorbed by the home demand, though iron castings, fences, gates, etc., have been shipped to Buenos Aires; some gas producers have been shipped to Armenia. The electric-meter output is sold in Italy. As this branch of the business is hardly 10 years old, and as German, French, and American competition must be met in the company's home market, it has not felt justified in attempting to compete in foreign markets.

SOCIETÀ ANONYME SIRY, CHAMON & C.

The Società Anonyme Siry, Chamon & C., of Milan, manufactures gas machinery and other appliances, including gas meters. Fixtures for gas and electric light are made in a great variety of designs, some of which are very artistic. These fixtures differ in one detail of construction from many American designs in that solid castings are used for many parts that in American fixtures would be made of stamped or spun sheet metal.

In addition to the foregoing principal items, the company also makes water meters and electric meters. The annual output of electric meters amounts to from $135,000 to $154,000, the selling price per meter ranging from $9.65 to $57.90.

The company's works are located at 95 Via Savonna, in one of the manufacturing portions of Milan. The buildings are modern and well lighted, with saw-tooth roof construction.

The company, being a branch of a French concern manufacturing electric meters, has found it desirable to procure all the meter parts from the Paris factory; thus the work here consists only of assembling and testing new meters and repairing old ones. Two large rooms suffice for this work, and 16 men are employed.

The working day is 10 hours; payment is on the piecework basis. For example, meter testers are paid 30 centesimi (about $0.06) per meter, and at this rate can earn 3 to 5 lire ($0.58 to $0.97) per day. Assembly and repair work are done in lots under piecework contracts made with the employees by an experienced foreman, who decides for each lot what to offer for the work. The methods in use in the meter department presented no special features requiring description. One feature of construction of the meters may be mentioned, namely, the use of copper disks for all meters.

The company insures its men against accident, and the men maintain a sick-benefit fund. It is stated that no trouble from strikes has been experienced. The company sells all its electric-meter output in Italy and also sells the other electrical instruments made by the Paris house.

SOCIETÀ EDISON PER LA FABBRICAZIONE DI MACCHINE ET APPARECCHI ELETTRICI.

The Società Edison per la Fabbricazione di Macchine et Apparecchi Elettrici, C. Grimoldi & C., is located at 6 Via Broggia, Milan. It manufactures and deals in dynamos, motors, switches, and other materials, and is the sole maker for Italy of the Wright maximum-demand meters, for indicating the maximum value of the electric current taken by consumers.

From 2,000 to 3,000 of these are made annually. These meters are very simple, and require little manufacturing equipment. The glass tube filled with sulphuric acid, which is an essential element, is made for the firm by outside glass blowers. The meters are tested in lots connected in series, and the readings are taken on a movable millimeter scale which is applied to each meter in succession. A curve is plotted for each meter and a scale is laid out to fit it.

The company also makes induction watt-hour meters, the annual production being about 500 meters. The company has manufactured direct-current watt-hour meters similar to the Thomson in principle, but at the present time is making very few of these, as it intends to redesign this type.

ADDITIONAL NOTES.

An Italian electric railway engineer states that much American electric railway material is used in Italy, in spite of its higher cost as compared with similar material from other sources. The reason for this preference, he says, is that the American material outlasts the others and stands more abuse; motormen have found that they can throw the current on as rapidly as they choose with American motors, while other makes will not stand such handling. He adds

that the American makers have a good many years' more experience back of them and have learned how to make durable apparatus.

The Milan Edison Co. has in service about 35,000 meters, of which a large number are Ferranti alternating-current induction type and Ferranti direct-current mercury type. They also use some Thomson meters of French manufacture. They have tried one of the prominent American meters for alternating current and found it better electrically than the Ferranti, but not so capable of standing the rough handling that meters are liable to get in transportation to and from the premises of consumers. The American meter in question has a pressed sheet-metal case; the Ferranti meters have strong cast-iron cases and are quite heavy. In testing the customers' meters in position, they prefer the wattmeter and stop-watch method to the use of portable rotating standard watt-hour meters, partly because of the troublesome correction curves of the latter. The rotating standard is used of necessity for motor installations where the load fluctuates rapidly. They test at 10, 20, 50, and 100 per cent of rated load. The equipment and methods used in the meter-testing department are not appreciably different, in a general way, from those used in the larger American stations. A card index of the meters is kept in quadruplicate (1) by the maker's serial number, (2) by the Milan Co.'s serial number, (3) by the customer's name alphabetically, (4) by streets. In addition, several colors of cards are used; for example, white for light, another color for power, another for "forfait" system, and so on. The principal data in regard to the meters are also kept in books arranged according to the Milan Co.'s serial (accession) number.

The frequency most commonly used in Italy is 42 cycles per second; 40 and 50 cycles are used, though not to a great extent.

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